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Understanding Distortion and Biases in Individual Information Processing under Social Impact

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the requirements for the degree of
Doctor of Philosophy

by

Yonghua Cen

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CERTIFICATE OF AUTHORSHIP/ORIGINALITY

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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- **Yonghua Cen**, Ping Zhang, Yingnan Xu, Hong Zhang (2015). Research on Technology Acceptance of E-Commerce Recommendations: Perspectives of Consumer Cognition. Science Press, Beijing, China. (ISBN: 978-7-03-046205-3)

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- **Yonghua Cen***, Linling Tao, Dandan Ma, Xiaoshu Wang (2016). A Review of Behavior Diffusion in Social Networks: Theories and a Dual-Observation Framework, *Information Studies: Theory and Application (China)*, 39(8), pp.133-138, To be Appeared.

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Abstract

Individual information processing and attitude development are fundamental aspects in a variety of decision-making scenarios. They are also important topics concerned in decision sciences, behavioural economics, psychology, and social sciences in recent years. Human information processing is always carried out in specific social contexts, where the implicit, imaginary or real presences of other individuals or organisations have potential impact on human attitude formation and decision-making. Along with the rapid innovations in interaction channels and interplaying patterns of social interactions, especially those facilitated by the ongoing growth of Internet technologies, the study of individual behaviour mechanisms with social impact has become the frontier and focus of a variety of relevant disciplines.

In existing research regarding information processing, information distortion, cognitive biases and heuristics, the influence of other individuals or groups and the complex and dynamic evolution of such influence in a longer spatial and temporal context with different population compositions are often overlooked. At the same time, the majority of previous studies investigating social impact at the collective scale of society laid major emphases on the dynamics of social networks, which define stylish individual rules but lack robust empirical validation. Therefore, to understand the distortion and biases in individual information processing under social impact, especially in specific application scenarios, a more reliable way is to delicately integrate the individual information processing at the bottom level with the social impact and system dynamics at the top level. This reflects the very starting-point

of the present research and a major aspect towards breakthrough research.

The major work in this thesis proceeds from the conceptualisation of several critical attitude-relevant constructs and the design of their measurements in the light of literature. These constructs surround attitude, cognitive dissonance, information distortion and cognitive bias, which are mathematically pictured. The conceptualisation and measurement development of these constructs build a scaffolding for further empirical analysis at the individual level and social computing at the societal level. At the same time, the measurement design affords a substantial solution in response to the notable lack of research attempts quantitatively capturing the complicated intra-psychological mechanisms underpinning individual information processing and the consequential distortion and biases.

Building on this conceptualisation and measurement design, as well as a comprehensive review of massive cross-discipline literature, this research further elaborates a conceptual model to explain the procedures and causal mechanisms of individual information processing and attitude development, and penetrates into the precursors of distortion and biases at the individual level. The model includes perceived argument quality and adequacy, source credibility and individual prior attitude as exogenous latent constructs (causal variables), and incorporates elaboration/sense-making, perceived message attitude, individual posterior attitude, distortion and bias, as endogenous latent constructs (effect variables). Particularly, the study accentuates the effects of cognitive inconsistency between the prior attitude of an individual and the attitude advocated by the message (i.e., cognitive dissonance) on posterior attitude, distortion and bias. The conceptual model was tested by following a typical empirical approach from stimuli manipulation, instrumentation, experiment design, data collection, to data analysis and findings discussions.

This empirical study at the individual level leads to the findings as follows: (1) perceived message quality and perceived source credibility have positive impacts on an individual's elaborating and making sense of an incoming per-

suasive stimulus, which contributes to the individual's attitude shift towards the stimulus advocacy; (2) the state of cognitive dissonance drives an individual to distortedly and biasedly process the inconsistent cognitive elements implied in an persuasive stimulus, which then restrains the individual from moving towards the stimulus advocacy; (3) individuals' elaboration of an incoming stimulus for sense-making and their information distortion for consistency are two paralleling and competing forces for attitude construction, which reflects the complicated nature of human information processing behaviour; (4) cognitive dissonance plays a critical role in the two competing forces; (5) sequential exposure to advocacy-consistent stimuli may gradually alleviate an individual's information distortion and cognitive biases.

As the most important aspect of the existing research, social computing is introduced to describe the information distortion and cognitive biases at a societal level. In the light of knowledge acquired from the empirical study at the individual level, an integrative model conceptualising the causal and procedural relationships involved in individual information processing is elaborated, which is bridged with a social contagion model. These dual theoretical models are further translated into computational models, where the variables concerning society, agent population, messaging and external persuasion campaign, as well as the transitional functions reflecting the relationships between the variables, are mathematically defined. Drawing upon the social computational results, the complexity of information distortion and cognitive biases situated in social impact is unravelled.

Major findings in the social computing work at the societal level are below. (1) Without interactions with others, people keep silence and isolated, maintaining stable attitudes. When people interplay with others, their attitude may alter. (2) When the whole society manifests a skew towards an extreme, the substantial majority stands together with high agreement, and their attitudes soon polarise. Those limited dissenters who feel isolated and severe conflicts with the majority will champion their positions in a strongly distorted way. Furthermore, when a non-polarised majority dominates the

minority, the former convert the latter while consolidating their own places. When they are mixed with two matching opposite forces in a society, the effect of neutralisation or negotiation governs the evolution of attitudes, the overall value of the society may converge to a point. (3) The null hypothesis asserted by most social psychologists only holds true in the condition where individuals will not distort the social information presented to them. However, in reality where people often distortedly or biasedly process the issue-relevant information, it is a long way (or even no way) to reach the uniformity and convergence, and there are substantial distortion and biases especially for the minority party. (4) A highly interconnected and fluid society entails active and frequent exchanges among the reshuffling members, leading to intensive changes in social states. The more interconnected a society is, the less distortion and biases happen; and when social cognition converges, the distortion and biases therefore disappear, due to the reached agreement. (5) A homogeneous society is more likely to reach a uniformity and convergence, whereas a heterogeneous society is more likely to end up with chaos, antagonism, and polarisation. These findings deserve intensive attention. (6) Individuals are often exposed to external influence information sources, such as massive media, lectures, promotions, and other kinds of persuasive campaigns, while exchanging with surrounding people. These campaigns interplay with communicative social information, and facilitate or suppress their cognition.

This research entertains the frontier concerns in the associated fields. It is expected to provide meaningful insight for further theoretical and methodological research as well as applications of individual information processing and attitude formation.

Chapter 1

Introduction

1.1 Background

The decision-making (judging or choosing) of human beings is essentially their cognitive processing of information (i.e., messages or stimuli they are exposed to) and their attitudinal and behavioural development based on this mental processing. In general, the messages or stimuli convey information concerning options/alternatives, attributes, sources, evidence or cues, attitudes, etc. Human information processing and attitude formation is a complex process influenced by multiple factors, including characteristics of personality, source, message, task, context, and so on (Ajzen 1991, Chaiken 1980, Cohen & Reed 2006, Petty & Briñol 2008, Petty & Cacioppo 1986). Due to the biological limitations of the information processing function of human minds, as well as the incompleteness of information resources (e.g., time) human beings can possess, human judges always end up with bounded rationality (Simon 1955, Simon 1956). Humans seem to employ heuristics to reduce their cognitive effort in information processing, that is, humans may make fast decisions by substituting the complete information required by the decision-making task with the incomplete information first coming to their mind (Shah & Oppenheimer 2008). The design of human information processing system is inherently imperfect and accompanying with this skewed

design is information distortion and cognitive biases (Hilbert 2012).

More concretely, information distortion refers to the process that a boundedly rational individual biasedly evaluate the message they receive, motivated by the goals of effort saving or cognitive consistency (Petty & Briñol 2008, Russo, Carlson, Meloy & Yong 2008, Shah & Oppenheimer 2008); cognitive biases, as the outcomes of information distortion, are the systematic deviations that distinguish the beliefs that people maintain and the choices they make from the optimal beliefs and choices normatively predicted by rational-agent models (DellaVigna 2009, Haselton, Nettle & Andrews 2005, Hilbert 2012, Kahneman 2003).

As fundamental aspects, individual information processing and attitude development are shared by a variety of decision-making scenarios, including choice and judgement (Bazerman & Moore 2012, Hilbert 2012, Tversky & Kahneman 1974, Tversky & Kahneman 1981), marketing and investment (Barber & Odean 2000), organisation behaviour (Alti & Tetlock 2014), consumption, selling and persuasion (Shah & Oppenheimer 2008), information dissemination (Koh & Sundar 2010, Laidre, Lamb, Shultz & Olsen 2013), democracy and politics (Ahn, Huckfeldt, Mayer & Ryan 2013, Arceneaux 2012), and so on, where bounded rationality in individual decision-making is also an important concern in the fields of decision sciences, behavioural economics, psychology and social sciences in recent years (Bazerman & Moore 2012, Kahneman 2003, Shleifer 2012). The very studies have supplied remarkable supplements for neo-classic microeconomics drawing upon optimization-based decision-making models (Crawford 2013, Harstad & Selten 2013, Rabin 2013).

Significantly, human information processing is always carried out in specific social contexts, where the implicit, imaginary or real presences of others have potential impacts on human attitude formation and decision-making. Along with the rapid innovations in channels and interplaying patterns of social interactions especially facilitated by the ongoing growth of Internet technologies, the mechanisms of individual behaviour under social impact have

become the frontiers and focuses of a variety of disciplines (Ahn et al. 2013, Aral & Walker 2012, Centola 2010, DiFonzo, Bourgeois, Suls, Homan, Stupak, Brooks, Ross & Bordia 2013, Iñiguez, Tagüeña-Martínez, Kaski & Barrio 2012, Iyengar, Van den Bulte & Valente 2011, Krumme, Cebrian, Pickard & Pentland 2012, Levitan & Verhulst 2016, Lewis, Gonzalez & Kaufman 2012, Lorenz, Rauhut, Schweitzer & Helbing 2011, Moussaıd, Kämmer, Analytis, Neth & Szolnoki 2013, Muchnik, Aral & Taylor 2013, Sobkowicz & Preis 2013, Sueur, Deneubourg & Petit 2012).

Nevertheless, in theoretical construction and empirical analysis, most of prior research regarding information processing, information distortion, cognitive biases and heuristics has technically ignored the influence of other individuals or groups, and the complex and dynamic evolution of this influence in a longer spatial and temporal context with different population compositions (Mason, Conrey & Smith 2007, Smith & Conrey 2007). At the same time, most of previous studies investigating social impact at the collective scale of society laid too much emphases on the dynamics of social networks by defining stylish individual rules which lack robust empirical validations (Mason et al. 2007, Moussaıd et al. 2013, Sobkowicz 2009, Sobkowicz & Preis 2013). Therefore, to understand the distortion and biases in individual information processing under social impact especially in specific application scenarios, a more reliable way is to delicately integrate the research line of individual information processing at the bottom level with the research line of social impact and system dynamics at the top level. This is the very starting-point of the present research. It is also the major aspect the research attempts to break through.

Information distortion and cognitive biases in individual decision-making may give rise to awkward judgements or sub-optimal decisions (such as misunderstanding, sentimentalism, weakening of self-consciousness and being credulous, selective attention, conservativeness or overconfidence, small number sampling and over-extrapolation, excessive avoidance of small risks, frame-depending and myopia, loss aversion under endowment effects, narrow

mental accounts, and so on), failures of management decision-making (in the areas of R&D, pricing, marketing, investment, finance and competitive strategy development, etc.), bankruptcy, financial market disorder, deterioration of public services, judicial injustice, governance failures, and so on (Bazerman & Moore 2012, DellaVigna 2009). Under social influence, biased judgement and sub-optimal decision-making (of individuals or organisations) may be further escalated and end up with the disruption of economic and social order, the sub-health of society value orientation, the worsening of social public credibility and social coherence, critical emergencies, international political crises, and even war and other catastrophic consequences. Insights into information distortion and cognitive biases in individual decision-making and their evolution under social influence, are instructive for individuals, firms, governments, political advocates, as well as media, etc., to make and implement more effective decisions, or convert the negative effects of individual bounded rationality and social influence into positive forces facilitating the achievement of decision-making objectives (DellaVigna 2009).

In response to the gaps in scholarly inquiries and the issues behind the above stressed real-world phenomena, the present research seeks to disclose the internal mental mechanisms of distortion and biases in individual information processing and the effects of social contexts. The research concerns the frontier aspects of some fundamental and hot fields. It also accommodates the behaviour science in big data environments. It is expected to provide insights for understanding the emergent social effects in different decision-making contexts.

1.2 Research Issues

In general, the focus the present research can be simplified as: with respect to a specific topic or advocacy, in a context of sequential processing of messages advocating incongruent attitudes, how do individuals of different characteristics process and evaluate the messages? What kind of distortion and biases

may come about? How does social interaction between individuals influences individuals' attitude development? What kind of aggregate effects at the societal level may emerge?

With regard to the above focus, in lights of the mass of prior studies, the niches of the present research can be identified from the following folds:

1.2.1 Intra-Psychological Mechanisms of Distortion and Biases in Individual Information Processing

Human information processing and attitude development is essentially a process involving stimulus perceiving, memory retrieving and activating, sense making and learning, anchoring and adjusting, as well as counter-arguing and discrepancy processing, and so on (Bohner & Dickel 2011, Cohen & Reed 2006, McGuire 1968). In this process, when exposed to external messages, individuals retrieve and integrate the knowledge stored in their memories, make mental elaborations, and shape their attitude and behaviour. The process mirrors the decision making behaviour of individuals of bounded rationality, and is affected by a variety of factors associated with individual personality, source, message, context and so on (Ajzen 1991, Chaiken 1980, Cohen & Reed 2006, Petty & Briñol 2008, Petty & Cacioppo 1986). Distortion and biases are inherently the outcomes of this kind of complex effects. Information distortion and cognitive biases in individual information processing is fundamental in understanding individual behaviour, which makes the first aspect of what the present research seeks to solve.

Most of pertinent research concerning individual information processing shed lights to the development process of attitude and the different routines of cognitive processes from the perspectives of psychology (Ajzen 1991, Chaiken 1980, Chaiken & Eagly 1989, Fishbein & Ajzen 1975, Gawronski & Bodenhausen 2006, Hovland, Janis & Kelley 1953, Kruglanski, Pierro, Mannetti, Erb & Chun 2007, Kruglanski & Thompson 1999, McGuire 1981, Petty & Cacioppo 1986), and elaborated a variety of cognitive information processing models including Elaboration Likelihood Model (Petty & Cacioppo

1986), Heuristic-Systematic Model (Chaiken 1980, Chaiken & Eagly 1989), and Associative-Propositional Evaluation Model (Gawronski & Bodenhausen 2006), etc. This research line maps individual mental activities onto a cognitive space, assuming that thanks to the limitation of individual cognitive resources, the association patterns in individual memories cannot be activated equally, the set of propositions individuals can construct is incomplete, and individuals cannot make equal reasoning towards each persuasive evidence or proposition (Bohner & Dickel 2011). These studies lay the foundation for the present research to understand the processes, motivations and influencing factors associated with individual information processing. However, the very research program has not furthered into the abnormalities of individual information processing, such as selective exposure to information, information distortion, cognitive biases, heuristics and so on.

Studies surrounding information distortion accentuate the phenomena of selective attention (Best, Chmielewski & Krueger 2005, Jonas, Schulz-Hardt, Frey & Thelen 2001, Lundgren & Prislin 1998), and the needs for cognitive consistency (Russo, Medvec & Meloy 1996, Russo et al. 2008) in individual information processing from the perspective of cognitive dissonance (Festinger 1957), assuming that human systematically prefers to the information consistent with their own belief, attitude and decisions, at the same time ignores inconsistent information to reduce their cognitive dissonance (Elliot & Devine 1994, Festinger 1957, Lord, Ross & Lepper 1979, Polman & Russo 2012) (Brownstein 2003, for a review).

Direct research concerning cognitive biases and heuristics primarily aimed at identifying the existence of different cognitive biases and heuristic effects through psychological experiments, and proving the outcomes of these biases and heuristics (Baron 2007, Hilbert 2012, Tversky & Kahneman 1974). In the book, *Thinking and Deciding*, Baron (2007) explicated more than 50 biases and heuristics. Besides, online Wikipedia lists more than one hundred biases of probability, belief and behaviour[1], and the list is still expanding.

[1]https://en.wikipedia.org/wiki/List_of_cognitive_biases

Heuristic strategies in information processing are the major trigger for cognitive biases. Simon (1990, p.11), the father of heuristics research in judgement and decision-making, argued that heuristics are "methods for arriving at satisfactory solutions with modest amounts of computation". By reviewing an abundance of effects associated with biases and heuristics, Shah & Oppenheimer (2008) posited that heuristics are the shortcuts that humans employ to reduce the cognitive cost (i.e., to save the effort) during information processing; these shortcuts rely on principles for effort-reduction including examining fewer cues, reducing the difficulty associated with retrieving and storing cue values, simplifying the weighting principles for cues, integrating less information, examining fewer alternatives, etc.

Essentially, information distortion resultant from selective exposure to information, as well as cognitive biases as consequences of heuristics, can be attributed to individuals' goals of effort-saving or cognitive consistency (Russo et al. 2008, Shah & Oppenheimer 2008). However, few efforts have been dedicated to investigate the internal mental mechanisms and associated causal factors behind information distorting, biased processing and heuristics. As pointed out by Shah & Oppenheimer (2008), information distortion, biases and heuristic effects detected in relevant research are mostly framed in specific decision tasks and to some extent cannot be regarded as common knowledge for understanding individual information processing. How motivational and cognitive explanations of individual information processing can be combined to yield a more complete understanding of selective exposure to information, information distortion and biases, is an open issue for further exploration (Bohner & Dickel 2011).

Besides, substantial part of the studies regarding abnormalities in cognitive information processing underlined qualitative psychological explanations while somewhat ignored the quantitative measurements of distortion and biases. This treatment to some extent cannot precisely capture the details of how different factors lead to information distortion and cognitive biases.

In summary, with respect to the first aspect of the present research, it

is essential to design the quantitative measurements of distortion and biases, investigate the intra-psychological mechanisms of distorted information processing and biased judgement, and construct the conceptual theoretical model at the individual scale.

The issues at this research aspect therefore involve:

I1: What are the underlying mechanisms and influencing factors driving distortion and biases in individual information processing?

I2: How to measure the distortion and biases?

Answers to these issues are instructive for understanding the regularities controlling information distortion and cognitive biases at the individual scale.

1.2.2 Contextual Effects of Social Impact on Distortion and Biases in Individual Information Processing

As socialized individuals, human is always situated in specific social context and is subject to the impact of social factors. Human psychological states and subjective feelings, motives and emotions, cognitions and beliefs, values and behaviour are affected by the real, implied or imagined presence or actions of others (Latané 1981). Furthermore, behaviour laws operating on lower levels of social reality (i.e., human individual) may have unforeseen, seemingly emergent, consequences for higher levels, which, in turn, will affect the social environment facing lower level units (Nowak, Szamrej & Latané 1990).

Prior studies surrounding information processing, information distortion, cognitive biases, and heuristics, as discussed formerly, have technically ignored the influence of other individuals or groups. Few emphases have been laid on systematically analysing the influence of other individuals in the social network of a target individual on the information processing (especially distortion and biases) of the individual, in a bottom-up way observing the social interaction and evolution of individual attitudes and preferences at the

collective scale of the society, and therefore unveiling the formation mechanisms of social information distortion and cognitive biases. This is the second aspect of the current research.

With regard to social impact, most researchers (Ahluwalia 2000, Ajzen 1991, Asch 1951, Brehm & Brehm 1981, Deutsch & Gerard 1955, DiFonzo et al. 2013, Fishbein & Ajzen 1975, Fishbein & Ajzen 1981, Janis 1982, Latané, Williams & Harkins 1979, Latané & Wolf 1981, Levitan & Verhulst 2016, Moscovici & Zavalloni 1969, Myers & Lamm 1976, Sherif 1935) (Cialdini & Goldstein 2004, for a review)in psychology examined individuals' psychological responses to others' presences, for example, compliance with others' beliefs and expectations, obedience to majority opinions, authority and social norms, and resistances in response to discrepancy. The researchers in this community also attempted to understand the social effects resulting from these responses, such as compliance, obedience, conformity, polarization, minority/majority influence, social facilitation/inhibition, social loafing, group thinking, and so on. They investigated the driving motivations of these responses and effects, including accuracy motivation, attribution motivation, self-concept motivation, and defence motivation, etc. Their research was primarily grounded in the fundamental social impact theories, including social learning theory (Miller & Dollard 1941), social cognition theory (Bandura 1986), social comparison theory (Festinger 1954), cognitive dissonance theory (Festinger 1957), and so on.

However, as pointed out by Mason et al. (2007), although laboratory experiments can somewhat capture the causal mechanisms of social impact on individuals' cognitive processing of information on the basis of classic psychological assumptions, they lack the capabilities to picture a complex and dynamic social system where interactions and interplays among different individuals take place in a longer spatial and temporal context with a huge population.

In a paralleling line, thanks to the computation technologies, researchers from many fields (especially physics and complex systems) underlined the

dynamics of opinions evolution at the top level of society (such as a large-size crowd under a particular situation) and innovated a variety of influential quantitative models, such as the majority rule model (Galam 1990), dynamic social impact model (Nowak et al. 1990), opinion dynamics model (Sznajd-Weron & Sznajd 2000), bounded confidence model (Deffuant, Neau, Amblard & Weisbuch 2000, Hegselmann & Krause 2002), continuous opinions and discrete actions (CODA) model (Martins 2008), etc. These models were leveraged to measure the diffusion paths and the convergence/divergence of behaviour and opinion under social impact (Altafini 2012, Centola 2010, Sueur et al. 2012). The models were seeded from specific initial population distributions, and were fed different social network features in terms of connectivity, heterogeneity, dynamics, and so on. Various remarkable network models were identified, including the small-world network model (Watts & Strogatz 1998, Zanette 2002), scale-free network model (Barabási & Albert 1999) and other complex social network models (Newman 2003) (Sobkowicz 2009, for a review).

By observing social impact at the collective scale of society, a lot of interesting patterns of complex social networks and dynamic opinion evolution were detected. However, since investigations at this scale lack rigorous validations of assumptions concerning individual behaviour, they cannot precisely capture the underlying process of social influence (Mason et al. 2007, Moussaıd et al. 2013, Sobkowicz 2009, Sobkowicz & Preis 2013).

Therefore, to understand the processes of social impact especially in specific application scenarios, a more reliable way is to integrate the cognitive information processing mechanisms of individuals at the bottom level with the evolutionary mechanisms of complex systems at the top level(Cen, Tao, Ma & Wang 2016). This is the very starting-point of the present research. It is also the major aspects the research attempts to break through.

It is challenging to make dual-observation (i.e., observe the information processing at the micro level of individual and the social interaction and evolution at the macro level of collectivity) in a same research de-

sign framework, where two models must be delicately devised (Mosler & Martens 2008, Sobkowicz 2009): one that reflects the intra-psychological change processes of individuals with reference to their information processing and environmental behaviour, and the other that represents the inter-individual contagion effects with in a social system, namely, social network model.

Notwithstanding, the dual-observation barely means simply connecting the individual model and the social system model. Alternatively, it involves thoroughgoing deliberations on the two models. First, the micro model describes the single-directed process of individuals interpreting information, while the macro model depicts the process of inter-individual interaction as well as the interplay between individuals and governing interventions. As such, how to integrate these two kinds of processes? Secondly, social impact on individuals are exerted through the media of social networks, whose compositional and dynamical characteristics sensitively determine the consequences of social impact. Thus, randomly populated and connected social networks never mirror the real system of social impact. How to define and design the characteristic parameters of social networks and embed them into the dynamic evolution framework of social impact?

Only by these deliberations, can the dual-observation be possible. Undoubtedly, the bottom-up observations from individuals to society are the major challenge for the proposed research. Fortunately, the data accumulated by the emerging Internet-based media such as instant messengers, micro-messages, micro-blogs, SNS, open comments, and so on, provide a great support for training the characteristic parameters of real social networks. At the same time, a mass of relevant research also provides powerful methodological references for these research treatments (Aral & Walker 2012, Grabowicz, Ramasco, Moro, Pujol, Eguiluz et al. 2012, Lewis et al. 2012, Krumme et al. 2012).

In summary, research issues at the second aspect involve:

I3: How to conceptualise social impact?

I4: What are the contextual effects of social presences of others on individual information processing?

I5: How to elaborate observation models for appreciating social impact?

I6: How do social contact networks of different population compositions and dynamic characteristics account for the evolution of individual information distortion and cognitive biases?

I7: How to observe and explain this evolution?

Solutions to these issues help to recognise the laws associated with the access and mental process of individuals to social information as well as the diffusion of social information. Untangling these perplexities calls for building a dual-observation model, which integrates individual information processing with social interactions and evolution of attitudes, based on the laws at both the individual scale and the societies scale.

1.2.3 Testing and Refining the Theoretical Models: Laboratory Experiments and Simulations

The effectiveness of the dual-observation model describing individual information processing and social interactions and evolution of attitude should be further validated and refined through experiments. This is the third aspect of the proposed research.

The first approach to validating the models is laboratory experiments, which deal with: (1) designing information processing tasks, social contagion mechanisms, independent variables, dependent variables, controlled variables, participants grouping, etc.; (2) developing the experiment system of virtual online information processing which allows detailed tracking of participants' online behaviour; (3) recruiting participants; and (4) testing and refining the theoretical models through analysis of experimental data. However, with regard to laboratory experiments, there is a consensus that psychological experiments give only a partial picture of human behaviours and variable dynamics, thanks to the limited participants and the constraints

from laboratory settings and costs (Moussaıd et al. 2013).

Computer simulations make good complements, which are the second approach of the current research to testing the models. As argued by Davis, Eisenhardt & Bingham (2007), Simulations have the advantages in internal validity and facility with longitudinal, nonlinear, and process phenomena. Technically, the key design of simulating experiments is constructing the systems-theoretical model (Mosler, Schwarz, Ammann & Gutscher 2001) and identifying the decision functions corresponding to the rules of individual attitude adaption driven by multiple motivations, grounded in the theoretical models validated by psychological experiments. These decision functions are then transformed to the simulating decision model and are embedded into the simulation software for experimental observations.

Agent-based modelling (ABM) is a typical method of computer simulation. Since 1971 when Schelling pioneered ABM in analysing dynamic segregation[2], this method has been extensively applied in many research areas (Smith & Conrey 2007, for a review), as evidenced by an assortment of ABM tools including NetLogo[3], Swarm[4], Repast[5], and MASON[6], etc., which provides powerful assistance for relevant research.

For the present research, the emphasis is neither on the concepts of ABM, nor on the simulation tools, but on defining the relation functions for simulating based on theoretical models and empirical investigations. More specifically, the stress of agent-based simulations in the current research should be laid on comprehensive model definitions as to agents of different types, attributes of agents, social contagion networks, sub-group consisting of a cluster of agents, influencing and interaction behaviour between individual agents, between agents of different types and between different sub-groups, or in other words, translating the assumptions and influencing mechanisms

[2]There is a controversy regarding the origin of ABM, which this proposal refrains from stating and distinguishing.

[3]http://ccl.northwestern.edu/netlogo/index.shtml

[4]http://www.swarm.org

[5]http://repast.sourceforge.net

[6]http://cs.gmu.edu/ eclab/projects/mason

validated by prior studies and the empirical studies by the current research into decision models of computer simulations.

In relation to the above stimulating approach, the method of theory development based on computer simulations proposed by Mosler et al. (2001) can be regarded as a good reference. Given a theoretical model, the first step of this method is to precisely formulate the core statements of the model through scrutinizing the theoretical assumptions that have already been empirically tested or been substantially supported by facts and evidence. The second step is to model the theories in the form of a systems-theoretical model, where the variables embodied in the core statements and the transitional relationship among the variables (i.e., the transition functions) are identified. Implementation, the third step, is the realization of a simulating decision model, namely, the transposition of the systems-theoretical model of relations into computer programs. With the computerized simulation model, the theories can be further tested and refined. Then, the theories and simulation model can be applied in real-word decision-making scenarios. The exercises of the method by Molser, et al. (Mosler & Brucks 2001, Mosler & Martens 2008, Mosler et al. 2001) in persuasion and environmental campaigns proves the practicability of the method in the simulation experiments of the current research.

The two approaches of theory testing, i.e., empirical study and simulation analysis, should band together in developing specific theories. To achieve this complementary testing, the current research proposes an iterative feedback testing routine, which steps from explorative simulation experiments, confirmative psychological experiments, and replicative simulation experiments to refining simulation experiments.

As appealed by Mosler et al. (2001) and Smith & Conrey (2007), ABM approach should be brought into elaborating theories of social psychologies. At the same time, in line with this appeal, the investigations of the current research into distortion and biases in individual information processing under social impact can contribute an innovative case of implementation to the

methodological system of developing theories through computer simulations.

Therefore, at this aspect, the research issues primarily involve:

I8: How to test the models?

I9: How to conduct the laboratory experiments and simulation experiments?

1.2.4 Applications of Theories and Methodologies in Actual Decision-Making Context

Although the current research primarily entertains the fundamental theories and methodologies concerning the very topic, the soundness of the theories and methodologies should be tested in real-world applications. This makes the fourth aspect of the current research.

As proposed in the background section, online information environments can be the candidate application scenario. Specifically, research attempts can choose representative events of online information dissemination, and collect the real data regarding individuals, social networks and event evolution. Based on this data, research attempts can populate the initial society, set up the social network parameters for the simulation model, and map the event development into iterations of social evolution. By comparing the outcomes of the simulation iterations with the real-world event evolution, the reliability of the theories and methodologies can be verified. At the same time, the intervening measures (such as injections of media, scientific knowledge, or influence of opinion leaders, etc.) can be introduced into the simulation iterations so that the effectiveness of the interventions can be further assessed and the implications for governing online information environments can be drawn.

A sizeable literature has amassed regarding online information dissemination, shedding lights on the role of online networks in the routines, dynamics, clustering and communities formation of online information diffusion. For example, Sobkowicz & Preis (2013) elaborated a nonlinear emo-

tion/information/opinion (E/I/O) dynamics model to simulate the opinion evolution of a political forum in Poland. The researcher extracted two-year data of social networks and user reviews from the forum. Through simulations on the data with the E/I/O model, Sobkowicz & Preis revealed various characteristics of the forum associated with the dynamics of user opinions and emotions.

However, as stated formerly, available research associated with quantitative modelling and simulation experiments of online information dissemination are built upon the collective level of online society, where the rules and assumptions underpinning the development and diffusion of individual opinions somewhat lack solid empirical validations, let alone clear descriptions regarding the logic of distortion and biases. In the vein, the proposed research is expected to contribute incremental outputs to the booming research line concerning mechanisms of online information dissemination and evolution.

Besides, choosing online information dissemination as the scenario of applied observations is also for the purpose of practicability in terms of collecting population and structure data of social networks, as well as comparing the outcomes of the simulation iterations with the real-world event evolution. Actually, the observations and explorations of the current research in online information environments can be extended to other decision making scenarios, e.g., financial markets, by manageable modifications.

In summary, the research issue at this aspect is:

I10: How to interpret the theoretical and methodological research in real-world decision-making scenarios (e.g., online information dissemination) and seek solutions to the decision issues?

1.3 Research Contributions

The current research bridges the gap between the research line concerning information processing at the individual scale and the one regarding social

impact at the collective scale. More definitely, the major contributions of the current research cover the following accounts:

- It affords a solution in response to the notable lack of research efforts quantitatively capturing the complicated intra-psychological mechanisms underpinning individual information processing and the consequential distortion and biases. By mathematically designing the measures for attitude in different dimensions, cognitive dissonance, information distortion and cognitive bias, it adds to the literature and fill the gap of more precise quantitative analysis.(Chapter 3).

- It constitutes important avenues for examining the mechanisms underlying individual information processing. It provides more detailed and reliable empirical evidence for individual decision making and information processing. It serves as a basis and reference for understanding the behavioural laws behind individual decision making and information processing, for penetrating into the formation mechanisms of noises, distortion and biases in individual information processing, and for regulating and instructing information behaviour of individuals or groups. It complements and furthers the research concerning information processing and decision making at the individual scale by incorporating social impact which otherwise has long been disregarded. (Chapter 4);

- It provides reverse (bottom-up) supports in theories and methodologies for the body of top-down studies surrounding social impact and complex networks. By devising the dual-observation model consolidating individual information processing at individual level and social interactions and evolution of attitudes at collective level, the current research yields an alternative for observing the emergent effects arising from individual behaviour to group dynamics, and overcomes the lack of validation of assumptions behind individual behaviour and decision-making in the studies from the collective perspectives such as complex networks, opinion dynamics, crowd simulation, and so on. (Chapter 5)

- It makes an innovative case of implementing computer simulations in developing theories. In the fields such as psychology and behaviour economics, theoretical hypotheses and models were tested through psychological experiments, some of which were carried out by the notoriously controversial priming manipulations. Psychological experiments, due to their limited coverage of data samples and their constraints of laboratory settings and costs, may result in pseudo validations. As a paralleling method, simulation experiments are leveraged to test the theories by following the procedure of formulating the core statements of the models, constructing the systems-theoretical model, defining the transitional functions of the model variables, translating the systems-theoretical model to simulation models and computer programs, running simulations and checking the models. (Chapter 5)

1.4 Thesis Structure

The thesis is structured as follow:

Chapter 2 prepares the theoretical foundation for the further investigations, drawing upon a comprehensive review of the literature regarding information cognitive processing and attitude development, information distortion and cognitive biases, and social impact.

Chapter 3 rethinks the nature of and the relationships among several critical attitude-relevant constructs, including attitudes in different dimensions, cognitive dissonance, perceived message attitude deviation, information distortion and cognitive bias drawing upon the reviewed literature. This theoretical conceptualisation leads to a set of delicate measurements with regard to these constructs. This chapter serves as an important nexus from literature to further empirical study and social computing research. The measurement approaches are also the shared foundation for empirical models development at the individual level and the social computing model elaboration at the societal level.

Chapter 4 empirically studies the causal relationships underlying information distortion and cognitive biases within information processing and attitude formation at the individual level. A conceptual model is elaborated to depict these causal relationships, with the behind hypotheses developed, in the light of literature and the insight acquired in Chapter 3. The conceptual model includes perceived argument quality and adequacy, source credibility and individual prior attitude as exogenous causal constructs, and incorporates elaboration/sense-making, perceived message attitude, individual posterior attitude, distortion and bias, as endogenous effect constructs. To validate the conceptual model, the approach of structural equation modelling is adopted. The empirical study proceeds from stimuli design, instruments design, experiment procedure design to data sampling. Instrument modelling and structural modelling are conducted, and the majority of the hypothesised effects are confirmed. The interaction between elaboration for sense-making and information distortion for consistency, the critical role of cognitive dissonance as well as the effects of sequential exposure are discussed, resulting in enlightening findings.

Chapter 5 seeks to draw the picture of information distortion and cognitive biases at the societal level by reliance on the vehicles of social computing. A dual-observation model bridging the effects at the individual level and social impact at the societal level is devised. The model at the individual level refines the causal and procedural relationships involved in individual information processing on the basis of the knowledge gained in Chapter 4 and prior literature, by introducing moderating constructs such as knowledge and motivation. The model at the societal level sheds light on the composition, cognitive status and dynamics of a society structured on complex social networks. These dual theoretical models are further translated into computational models, where the variables concerning society, agent population, message and external persuasion campaign, and the transitional functions reflecting the relationships between the variables are mathematically defined. Drawing upon the social computational results, the complexity

of information distortion and cognitive biases situated in social influence is unravelled.

Chapter 6 concludes the thesis and outlines the scope for future work.

Figure 1.1 shows the research profile, also the technical roadmap of this thesis.

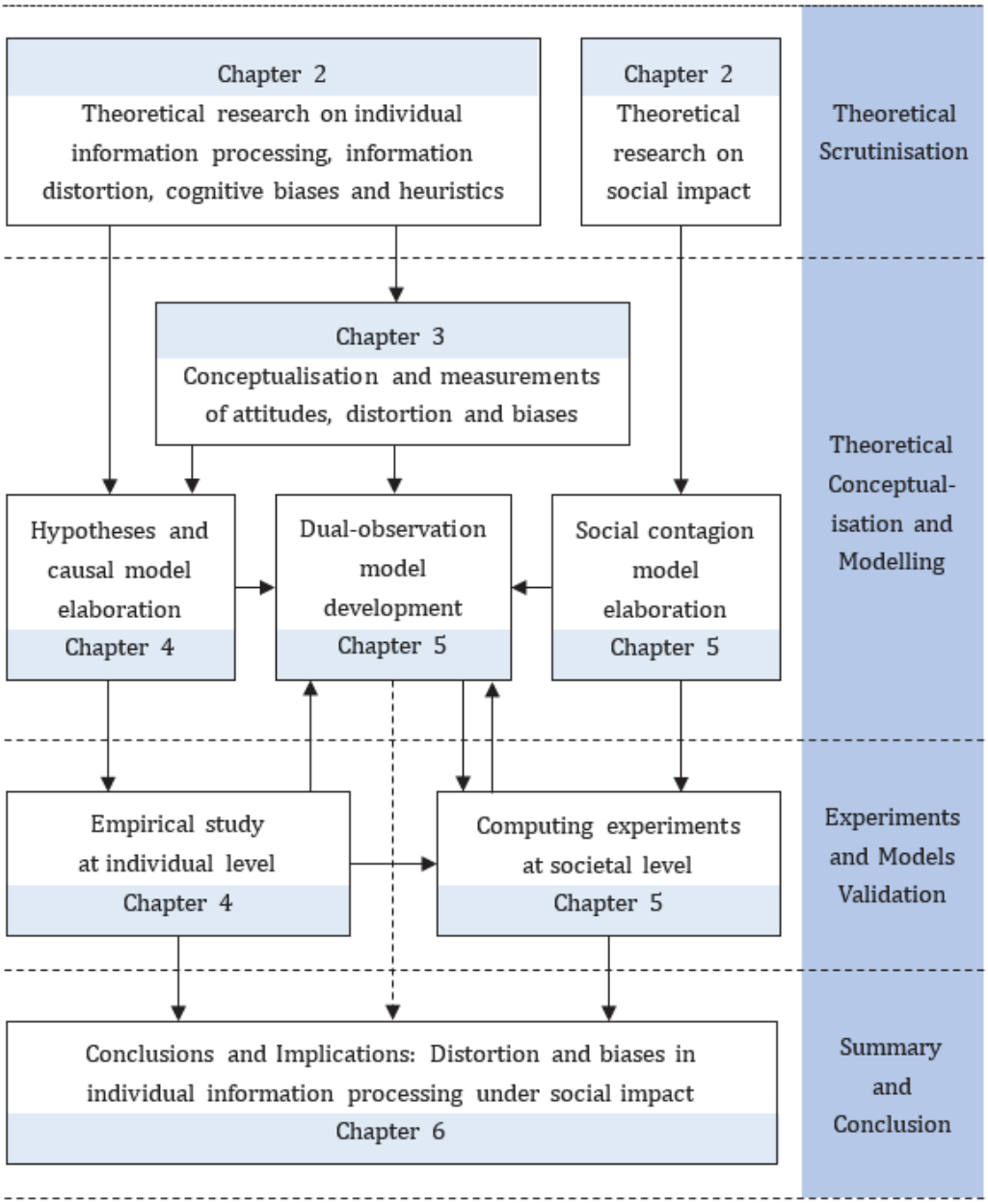


Figure 1.1: Profile of Work in This Thesis

Chapter 2

Literature Review and Theoretical Foundations

The eliciting of research issues in Chapter 1 presents snapshots of the major research lines related to the current work, i.e., information cognitive processing and attitude development of individuals, information distortion and cognitive biases, bounded rationality, social impact/influence, as well as computer simulation and social science computation. Knowledge regarding these lines comes from different disciplines, including psychology, economics, management, physics, computer science, sociology, politics, communication, etc., The cross-disciplinary perspectives, which are laid out and reviewed in the following sections, have paved a solid theoretical and methodological foundation for the present work.

The major aspects of the review and their roles in further empirical study and social computing are outlined as Table 2.1

Table 2.1: The Framework of Literature Review

Literature Categories	Research Modules	Limitations	Scaffolding for This Thesis
Information Cognitive Processing and Attitude Development	Processes and affecting factors	– Overlooks the influence of other individuals or groups and the complex and dynamic evolution of such influence in a longer spatial and temporal context with different population compositions; – Lacks quantitatively capturing the characteristics of individual information processing and the accompanying distortion and biases.	– The conceptualisation and measurements of attitudes, distortion and biases in Chapter 3; – The conceptual framework elaboration and empirical design in Chapter 4; – The design of the model at individual level in Chapter 5.
	Perspective of motivation		
	Discrepancy processing and counterarguing		
	Metacognition		
	Cognitive processing in sequential exposure contexts		
Information Distortion, Cognitive Biases, and Heuristic Processing	Bounded rationality		
	Heuristics		
	Cognitive biases		
	Information Distortion		
Social Impact	Perspectives in social psychology	– Lacks robust empirical validation of the stylish individual rules; – Lacks understanding the distorted and biased individual behaviour.	– The design of the model at societal level in Chapter 5.
	Effects of social impact		
	Dynamics and evolution of social impact at the system level		
	The role of social structure		

2.1 Information Cognitive Processing and Attitude Development

Information cognitive processing and attitude development has long been a fundamental concern in social psychology and marketing persuasion[1], amassing a variety perspectives, such as learning perspective, judgement perspective, motivational perspective, attributional perspective, belief perspective, self-persuasion perspective, etc.(Cacioppo, Petty & Crites 1994, for a summary), and concluding with different qualitative/descriptive and quantitative/mathematical frameworks, both theoretical and empirical, such as message-

[1]As described by the Prominent psychologist Gordon Allport (1935), attitude is the "*most distinctive and indispensable concept in contemporary social psychology*".

learning framework (Hovland et al. 1953) and its derivative, information processing theory (McGuire 1968), probabilogical model (McGuire 1981), the theory of reasoned action (Fishbein & Ajzen 1975) and the subsequent theory of planned behaviour (Fishbein & Ajzen 1981), elaboration likelihood model (Petty & Cacioppo 1986), heuristic-systematic model (Chaiken 1980, Chaiken & Eagly 1989), associative-propositional evaluation model (Gawronski & Bodenhausen 2006), the cognitive energetic theory (Kruglanski, Bélanger, Chen, Köpetz, Pierro & Mannetti 2012), regulatory focus model (Higgins 1997), the unimodel of persuasion (Kruglanski & Thompson 1999, Kruglanski et al. 2007), and so on. Major lenses in this research rubric are reviewed as follows:

2.1.1 Processes and Affecting Factors

As earlier classic theories concerning information cognitive processing, the message-learning framework (Hovland et al. 1953) and information processing theory (McGuire 1968) enquire into the sequence of steps individuals follow to form and change their attitudes upon exposure to a persuasive stimulus. The basic steps are attending, comprehending, assessing and comparing, and opinion changing. These theories posit that individuals shape their attitudinal valence (e.g., accept/decline, like/dislike, favour/disfavour, etc.) by comparing their own opinion to the attitude advocated by the stimulus, by highlighting individuals' information synthesizing, resisting and discrepancy processing during the comparison.

The probabilogical model (McGuire 1981) represents attitude change as a function of both logic consistency and hedonic consistency. Logic consistency demonstrates the effects of individuals' perceived probability of a specific proposition (i.e., an underlying belief is true) on their perceived validity of other logically related propositions (logic consistency). Hedonic consistency, on the other hand, refers to the tendency for individuals to come up with an assessment consistent with their expectation, even by sacrificing the logic. The theory of reasoned action (Fishbein & Ajzen 1975)

and its extension, the theory of planned behaviour (Fishbein & Ajzen 1981) were widely used for behaviour prediction. According to these theories, the proximal determinant of behaviour is intention, which in turn is a function of three psychological antecedents, i.e., attitude, subjective norm and perceived behavioural control. Specifically, the attitude is conceptualized as an individual's overall evaluation of the target behaviour, i.e., the sum of the individual's attitudinal belief of each possible outcome of the behaviour weighted by the individual's subjective evaluation of the desirability of the corresponding outcome. In a like manner, the subjective norm is modelled as summing up the product of an individual's normative belief that important others wish the individual to engage in the behaviour with the motivation of the individual to comply with others' judgements. The perceived behaviour control over the target behaviour is essentially individuals' overall assessment of their past experience, expected obstacles and available resources (e.g., the requisite opportunities, time, money or techniques to take the target action) by weighting their beliefs of controlling the behaviour with their perceived power in arranging their experience and requisite resources to facilitate or inhibit the behaviour. These theories afford the belief perspective and basic quantitative implications for information cognitive processing and attitude development of individuals. Combining with the utility functions in economics, they may equip the current research with the knowledge concerning the rules of individual decision-making.

As two exemplary dual-process theoretical models in social psychology, heuristic-systematic processing model (Chaiken 1980, Chaiken & Eagly 1989) and elaboration likelihood model (Petty & Cacioppo 1986) have greatly enlightened subsequent researchers in psychology and marketing persuasion, by looking into the different routes of people's cognitive processing of information received.

The elaboration likelihood model (ELM) (Petty & Cacioppo 1986) postulates the way in which individuals reach an attitude is dependent on the degree of their cognitive processing of issue-relevant persuasive arguments.

With the increase of individuals' capability and motivation to evaluate a message presented, the likelihood of individuals' thoughtful scrutiny of the message increases. The continuum of the likelihood of thoughtful scrutiny varies from the central route of processing with high elaboration to the peripheral route with low elaboration. When processing a stimulus via the central route, individuals' elaboration likelihood is high, and they will peruse the issue-relevant arguments communicated in the message, discern the creditable ones, and make objective judgement towards the arguments. Strong arguments draw individuals' attitude to the position advocated by the stimulus, while weak ones lead to an attitude departing from the persuasion direction. Meanwhile, individuals may overrate the value of those arguments maintaining a position consistent with their prior attitude, and suppress the inconsistent arguments in a biased way. Those arguments whose advocacies conforming with individuals' initial attitude are more possible to reach the persuasive objectives, whereas the arguments bearing positions discrepant to individuals' initial position are more possible to end up with the opposite. In the peripheral route, individuals demonstrate a low likelihood of elaborating the incoming information, and sometimes draw their value-orientation primarily upon peripheral cues, e.g., source expertise and credibility, the amount of arguments, entertaining musics, rhetorical elements, etc., but little upon the quality of arguments. Positive cues are more likely to drive individuals' attitude towards the persuasive direction, while negative cues are more likely to restrain individuals' attitude away from the desired direction. Compared to peripheral processing, attitudes resulting from central processing demonstrate greater temporal persistence, more predictability of behaviour, and stronger resistance to counterarguments. Besides, by thoughtful processing of incoming information, individuals can integrate new knowledge into their guiding attitudinal schema.

The heuristic-systematic processing model (HSM) (Chaiken 1980, Chaiken & Eagly 1989) assumes two basic routes for individuals to cognitively process information, i.e., systematic processing and heuristic processing. Similar to

the central processing in ELM, systematic processing involves comprehensive and profound analysis and evaluation to the information/arguments critical to the judgement task. The outcome of systematic processing is greatly sensitive to the semantics of the informational input. As a nonanalytic orientation, heuristic processing involves much less cognitive capacity and effort than systematic processing. Via this route, individuals tend to formulate their judgements and decisions grounded upon the expertise, trustworthiness, consensus, familiarity and popularity of the incoming information, by following simple inferential rules and cognitive heuristics. Here, heuristics are learned schemata stored in human minds, which can be recalled and activated either consciously or inconclusively. Systematic processing and heuristic processing can determine attitude changes either independently or simultaneously. When acting together, the two routes may either reinforce or attenuate each other, and heuristic processing may even bias the systematic judgement (Chaiken & Eagly 1989, Chaiken & Maheswaran 1994).

As another dual-processing model, associative-propositional evaluation (APE) model (Gawronski & Bodenhausen 2006) accounts for the interplay between implicit attitudes and explicit attitudes by decomposing the cognitive processing into two interdependent parts , i.e., associative evaluation and propositional reasoning. Associative evaluation is the major driver of changes in implicit attitudes. It depicts the emotional outcomes of specific associative patterns being automatically activated when individuals are exposed to a stimulus. The level of associations being activated is independent of the true values (e.g., true/false, accurate/inaccurate, like/dislike, etc.) of the associations, but rather regulated by the feature similarity and spatiotemporal contiguity between the judgement context and the associative patterns. The attitude object may be represented in a multifaceted manner and the presence of different context cues may activated different associative patterns reflecting different subsets of the object representation. Besides, an incremental change in the evaluative structure (e.g., evaluative conditioning) may also lead to the changes in associative evaluations. For example, a neu-

tral stimulus paired with a positive stimulus is more likely to end up with a positive judgement towards the stimulus than paired with a negative one. Propositional reasoning builds the basis for explicit attitudes. It involves individuals' affirmative and reflective judgements based on the syllogistic inferences derived from the propositional information relevant to the judgement of an incoming stimulus, including those activated associative evaluations and other propositions implied in the context cues. Changes in associative evaluations, the set of candidate propositions, as well as the strategy to achieve cognitive consistency are the major causes of propositional reasoning and therefore the changes in explicit attitudes. Gawronski & Bodenhausen (2006) explicated the complex interactions between implicit attitudes and explicit attitudes. For example, highly activated associative patterns (implicit attitudes) may result in changes in explicit attitude, whereas stressing specific propositional information during reasoning may temporally facilitate the activation of relevant associations (which in nature is the effects of selective attention or cognitive consistency). The increase of cognitive elaboration can reduce the interplay between implicit and explicit attitudes, by affecting the complexity of propositional reasoning due to the expansion of the pool of judgement-relevant propositions in addition to an individual's automatic affective evaluations. The APE model affords an integrative framework for understanding the intra-mechanisms of individuals' cognitive processing from the perspective of human memory structure (or biological structure) by incorporating associative evaluations. However, it does not give a clear picture regarding what in essence leads to the associative processing, and does not enquire into the factors impacting associative and propositional processing.

A series of dual-process models sharing similar underlying assumptions to the above ones were reviewed by Smith & DeCoster (2000), which the present thesis restrains from further stating.

Complementing to (or to some extent, competing with) the parlance of dual-processing, there have also been scholars investigating into the different energetic forces governing individuals' mental processing and attitude

development (Kruglanski et al. 2012, Chung & Fink 2008). For example, the cognitive energetic theory (CET) proposed by Kruglanski et al. (2012) adopts the field theoretic approach of Lewin (1953), assuming that purposeful cognitive processing is facilitated/propelled by a *driving* force, and prevented/opposed by a *restraining* force. The driving force originates in the combination of goal importance (i.e., personal involvement or relevance) and the pool of available cognitive resources, whereas the restraining force stems from individuals' tendency towards cognitive inertia, distracts, perceived difficulty of the judgement and competing goals.

In contrast to the dual-processing models, the unimodel of information processing (Kruglanski & Thompson 1999, Kruglanski et al. 2007) declares that there is no substantially differential routes for individuals to cognitively process incoming information. Evidence with different persuasive performance, i.e., semantic message arguments, peripheral cues, moods with attitudinal valance, etc., varies on a continuum of processing difficulty: evidence that can be easier to processed (e.g., due to its conciseness, low complexity, salience or temporally earlier presentation) is more likely to be judged with low cognitive efforts, whereas evidence that is relatively difficult to process (e.g., because of its informativeness, high complexity, obscureness or temporally later presentation) demands more cognitive efforts to achieve a judgement (Bohner & Dickel 2011, for a review).

As summarized by Bohner & Dickel (2011, pp.404), both dual- and single-processing perspectives share the assumptions that individuals' cognitive activities toward an input message are essentially projects/maps on a continuum of processing effort. The amount of cognitive effort an individual makes in processing an message is the function of their motivation and ability to process the message. Because the cognitive resources individuals can possess are limited, i.e., individuals are boundedly rational, individuals cannot process in depth the details of every persuasive evidence of the incoming message (Bohner & Dickel 2011). The associative patterns cannot be equally activated, and the pool of syllogistic propositions can be built is limited. As

a consequence, attitudes based on this incomplete cognitive processing may be distorted or biased.

The process, cognitive efforts (depth) and consequential attitudinal valence of cognitive elaboration are determined by a variety of characteristic factors (Ajzen 1991, Chaiken 1980, Cohen & Reed 2006, Petty & Cacioppo 1986, Petty & Briñol 2008), including characteristics of the source (i.e., the expertise, attractiveness, credibility, familiarity, etc.), characteristics of the message (i.e., the quality, quantity and strength of the arguments conveyed, salience/accessibility, complexity, spatio-temporal status of presentation, the hedonic and utilitarian nature, etc.), characteristics of the receiver (i.e., motivation, priors, capability, personality, feeling, meta-cognition, etc.), as well as the characteristics of the judgement task/context (e.g., distraction, time pressure, etc.). Impact of parts of the enumerated characteristics will be revisited in Chapter 4.

2.1.2 Perspective of Motivation

Motivations serve as not only the encouraging input, but also the expectation of outcome for an individual to cognitively engage in an issue-relevant judgement. In their theories of reasoned action and planned behaviour, Ajzen et al. (Fishbein & Ajzen 1975, Ajzen 1991) included the compliance motivation to represent the willingness of an individual to observe subjective norms, i.e., the opinions of important others. The theories conceptualise subjective norms as the function of normative beliefs and compliance motivations. In the elaboration likelihood model, Petty & Cacioppo (1986) argued that the likelihood for an individual to think over a message depends on the individual's elaboration capability and motivation, where motivation is function of personal relevance measuring the implicit significance of the message advocacies for the individual. In a different way, the heuristic-systematic model (Chaiken & Eagly 1989, Eagly & Chaiken 1993, Lundgren & Prislin 1998) underlines the effects of three different motivations on people's mental processing, i.e., accuracy motivation (representing people's desire to reach an

accurate attitude), defence motivation (indicating people's expectation to defend their own attitude) and impression motivation (portraying people's expectation of social identity). Under the three motivations, an individual on one hand will conserve cognitive investments by following the principle of least effort, and on the other hand will pay adequate cognitive cost to achieve sufficient confidence in the derived attitude (by following the principle of sufficiency). The probabilogical model (McGuire 1981) specifies attitude change as a function of individuals' motivations to pursue both the logical consistency and hedonic consistency. Another influential type of motivation is cognitive consistency (Festinger 1957), which has long been the underlying theory for most scholarly attempts in information distortion and cognitive biases, as will be accentuated in later sections.

The regulatory focus theory (Higgins 1997, Cesario, Grant & Higgins 2004) distinguishes two motivational orientations for regulatory fit, i.e., promotion focus and prevention focus. Promotion focused individuals conceive of their goal as aspiration and accomplishments, and are more sensitive to the presence of gain/nongain outcomes. By contrast, prevention focused individuals conceive of their goal as obligation and safety, and are more concerned with nonloss/loss outcomes. The sense of regulatory fit in cognitive processing resides in: promotion focused individuals are more willing to integrate the arguments consistent with the advocacy of the incoming stimulus, and make eager reflection and processing towards the advocacy, with the prospect of the positive results of the advocacy being implemented; contrarily, prevention focused ones are more likely to affirm the arguments incongruent with the stimulus advocacy, and make vigilant thinking with the caution of the negative consequences of the asserted advocacy.

Collectively, motivations in cognitive processing reflect individuals' perception of personal relevance, and their pursing of ego-defence (e.g., for cognitive inertia, effort conserving, and social identity), alignment (e.g., compliance motivation, impression motivation), regulatory fit, and so on. Different motivation acts in a different way on information sampling and synthesis,

elaboration, discrepancy processing, selective attention, information distortion and cognitive biases during individuals' mental processing in specific exposure contexts.

2.1.3 Discrepancy Processing and Counterarguing

The message-learning framework (Hovland et al. 1953) and information processing theory (McGuire 1968) seeded the notion that individuals make counterarguments and discrepancy processing towards persuasive evidence whose attitude is inconsistent with their own beliefs. Generally, once individuals are exposed to a persuasive appeal conveying a contradicting attitude, their mental conflicts (e.g., dissonance, resistance or negative emotions) are activated, and to avoid changes in attitude and maintain thinking inertia, they employ counterarguing strategies (Knowles & Linn 2004). Individuals' counterarguing to an incompatible attitude are determined by their commitment or conviction in their own attitude, their priors and their syllogistic elaboration on the message. The ELM model postulates that, when high elaboration is involved, those arguments incongruent to an individual's initial position are more likely to incur an attitude outcome reverse to the persuasion direction, which is essentially the boomerang effect. But this boomerang effect is always controversial without adequate empirical evidence, as declared by Hamilton, Hunter & Boster (1993).

Counterarguing is either the motivational input for individuals' mental processing (a motivation much resembling the aforementioned ego-defence), or the course or outcome of the processing. The major tradition of research regarding cognitive processing and attitude development actually sheds miserly lights on counterarguing and discrepancy processing. In an exposure context where sequential messages with multifaceted attitude valences are offered, however, the missing of counterarguing may end up with an attitude that is the average of an individual's initial attitudes and all the distributed message attitudes. In a like manner, in a context where different individuals interact with each other in an iterative way, failing to take into account the

effect of counterarguing and discrepancy processing may entail a converged and uniformed social attitude as the mean of the initial distribution of private opinions. This effect of neutralisation to some extent deviates from the real dynamics of sequential exposure, as well as the evolution of social or collective attitudes (Nowak et al. 1990).

On the other hand, counterarguing and discrepancy processing is also a solution to cognitive dissonance. Like people's tendency to cognitive consistency, it is also an non-negligible effect accounting for the distortion and biases in cognitive processing. The empirical research of the present thesis will provide evidence for this effect.

2.1.4 Metacognition

Another point has long been missed in the associated research is the mediating role of metacognition in individuals' information processing (Petty, Briñol & Tormala 2002). Metacognition depicts individuals' cognitive responses to the process and outcomes of their mental elaboration of the incoming messages (Schwarz & Clore 2007). One important aspect of metacognition is individuals' confidence in their cognitive processing and the outcomes (e.g., attitude shaped or changed). As indicated by the findings of Petty et al. (2002), when favourable elaboration predominates in response to a persuasive message, increasing individuals' confidence in their cognitive processing will boost the persuasive performance of the message; on the flip side, when unfavourable elaboration prevails, increasing confidence will suppress the persuasive performance. In other words, the valence of individuals' thoughts play a more significant role in shaping their attitudes when their thoughts are held with higher rather than lower confidence (Petty et al. 2002). This is essentially the self-validation effects in information cognitive processing, which is more likely to occur in the route of high elaboration, as concluded by Petty et al. (2002).

On one hand, the confidence of individuals in processing an incoming message is influenced by a plurality of factors, including individuals' affec-

tive experience, perceived ease of memory retrieval (i.e., processing fluency), prior confidence, perceived consensus, credibility of message source, and distraction, etc.(Petty et al. 2002, Schwarz & Clore 2007). Besides, those variables governing individuals' information processing and attitude formation also have their effects on their confidence. On the other hand, this confidence in turn influences the update of an individual's schemata, and the persistence and stability of the shaped attitudes. When individuals elaborate a message with high confidence, they are more likely to integrate the message arguments into their own cognitive schemata, and preserve the achieved attitude even when fed with new messages. The series of experiments conducted by Polman & Russo (2012) provide the evidence that individuals' confidence in cognitive processing and their commitment to the acquired preference or attitude positively predict individuals' counterarguing, information distortion and cognitive biases. Moreover, the current research insists that, when exposed to a social context, individuals' confidence in information processing and their subsequent conviction to the learned attitude can serve as an emotional cue to uplift their influence on socially contacted others.

2.1.5 Cognitive Processing in Sequential Exposure Contexts

The majority of the aforementioned research technically interpreted the reception of stimulus and cognitive elaboration as an independent process. However, individuals in real world are always exposed to a persuasion context of sequential messages, receiving and processing different stimulus communicating multifaceted or even controversial attitudes at different time points. The conviction in, and the persistence and stability of attitudes and schemata acquired as the effects of previous stimuli definitely influence individuals' cognitive processing of subsequent stimuli. As appealed by Bohner & Dickel (2011), further efforts should delineate the concept of relatedness of the pieces of information in a sequential exposure context and individuals' assimilation versus contrast to the multi-valenced stimuli.

2.2 Information Distortion, Cognitive Biases and Heuristic Processing

Under this rubric, different intercorrelated concepts regarding humans' intentional or natural deviation from the *economic* or *rational* behaviour, including bounded rationality, heuristics, cognitive biases and information distortion, are reviewed and theoretically bridged with an understanding framework of information sampling.

2.2.1 Bounded Rationality

Bounded rationality has been recognised as been coined about sixty years ago by Herbet Simon (Simon 1955, Simon 1956), the laureate of Nobel Prize in Economic Sciences 1978, as a competing notion with *rationality*, or a complementing notion, as argued by some defenders of rationality (Harstad & Selten 2013). Classical economic theories model the behaviour of an economic man as processes of optimization and rational adaptation, providing the constraints, such as the set of available alternatives, the function calculating the payoffs (i.e., utilities, satisfactions, goal attainment, etc.) of each alternative, and the preference ordering of payoffs (Simon 1955). The economic or administrative man is assumed to have every knowledge regarding the environments and have a well-organized and stable system of preferences, as well as complete capacity in gathering and computing the information about alternatives (Simon 1955). In contrast, according to Simon (1955), due to the limitation of cognitive facilities of an *organism* in the actual world, and the structure of environments it lives, the organism does well enough to satisfice, but rather in general to optimize (Simon 1956). The organism does so by simplifying the dimensions of classical rationality models, making it more realistic, while adhering to the relatively rigorous formalization. These simplifications include mapping a continuous utility function to discrete intervals, taking into account the costs of gathering and processing information, and partially ordering the payoffs by incorporating a vector or multi-valued utility function

rather than a scalar one (Simon 1955). Drawing upon the above rethinking of rational choice assumptions, Simon (1972) defined bounded rationality as the behaviour of individuals or organisations attaining for suboptimal decisions by substituting the stopping rule of utility maximisation with the one of satisficing, due to the risks and uncertainty, the incomplete information about alternatives and the complexity involved in a decision-making task. To achieve satisficing and searching for plausible alternatives, individuals always employ heuristic and trial-and-error approaches (Simon 1955). Moreover, Simon (1978) distinguished *substantial* rationality from *procedural* rationality. Substantial rationality is the basis or product of traditional economic models, describing the extent to which the goals are attained under the *givens* and constraints, whereas procedural rationality is the focus of behavioural economics, depicting the effectiveness of the procedure of action choosing, in terms of human cognitive capacities and limitations.

Another two epitomes of bounded rationality are Daniel Kahneman (the winner of Nobel Prize in Economic Sciences 2002) and Amos Tversky, who based their theories on the notion of *accessibility* (Kahneman 2003). Accessibility characterises "*the ease with which mental contents come to mind*" (Kahneman 2003, Tversky & Kahneman 1973). Generally, bounded rationality arises from some information relevant to a decision-making or judgement task being more accessible (i.e., salient or fluent) than others. In the technical sense of accessibility, the studies of Kahneman and Tversky encompass three separate aspects. The first aspect, which will be revisited next section, involves the heuristics people employ and the consequent biases in different judgement or choosing tasks under uncertainty (Tversky & Kahneman 1974). The second aspect concerns the famous model of choice under risk, i.e., prospect theory (Kahneman & Tversky 1979), which spotlights the accessibility of changes or differences. The theory challenges the conventional economic analysis, which postulates that the utility of a choice is totally determined by the final state of endowment, but independent with reference. Instead, the prospect theory assumes that the utility is a function of gains

and losses, both are *reference-dependent*. Back to the line of information processing, the nature of prospect theory resides in that human perception is reference-dependent, and those attributes reflecting the contrast between a focal stimulus and the patterns of prior and synchronous stimuli arrive at human minds more easily. The third aspect, i.e., the framing effects (Tversky & Kahneman 1981), stands against the essential assumption of rationality that trivial changes in the description of outcomes do not necessarily entail changes in preference. In contrary to this assumption, according to Tversky & Kahneman (1981), framing the different problem facets in different ways changes the relative salience of these facets, and therefore leads to different judgements or choices. Kahneman and Tversky elaborated the dual-systems of human cognition as a synthesising framework for understanding bounded rationality (Kahneman 2003). The two systems correspond roughly to intuitive thinking (System 1) and reasoning (System 2). System 1 functions in a fast, parallel, intuitive, associative way, and often regulated by emotions, habits or priors. System 2, by contrast, works in a slower, laborious and calculated way, and often governed by rules.

Although some economists have attempted to model bounded rationality in a quantitative way (Gigerenzer & Goldstein 1996, Rubinstein 1998, Simon 1982) or take account of bounded rationality by relaxing the constraints of neo-classic economic models (see discussions in the second issue of Journal of Economic Literature, 2013), so far, there is still a notable lack of research work providing the capability of observing and explicating how bounded rationality plays its role in information processing, in response to the appeal of Simon (1978) for more attention in the procedural rationality.

2.2.2 Heuristics

According to the satisficing principle of Simon (1955), a boundedly rational organism often draw on heuristics and trial-and-error to reach an end of satisficing. More concretely, Simon (1990, p.11) conceptualised heuristics as "*methods for arriving at satisfactory solutions with modest amounts of com-*

putation", i.e., simple processes rather than complex calculations involved in perfect rationality, e.g., as discussed above, mapping a continuous utility function to discrete intervals, and partially ordering the payoffs by incorporating a vector or multi-valued utility function rather than a scalar one, etc.(Simon 1955). In a like manner, Tversky & Kahneman (1974) asserted that, individuals follow a limited number of heuristic principles to reduce the complex computations in estimating probabilities and predicting to simpler judgement processes. In his lecture for Nobel Price, Kahneman (2003) argued that heuristic processing, as natural assessment, frequently happens in System 1. He then penetrated into two typical heuristics, including attribute substitution and prototype heuristics (or in a narrow sense, representativeness heuristics). By attribute substitution, individuals assess an object in terms of those more accessible heuristic attributes rather than the attributes significant to the judgement. By prototype heuristics, individuals build the impression of a specific object upon the general perception of its prototype. Another remarkable heuristic suggested by Tversky & Kahneman (1974) is anchoring and adjustment, which characterises how first thoughts or prior cognition occupy human minds and govern the subsequent mental search process. Grounded in a scrutinization of a wealth of heuristic effects, Shah & Oppenheimer (2008) generalised that heuristics are the shortcuts of which an individual takes advantage to conserve cognitive efforts during information processing. They enumerated the heuristic principles behind these shortcuts, including examining fewer cues, reducing the difficulty associated with retrieving and storing cue values, simplifying the weighting principles for cues, integrating less information, examining fewer alternatives, etc.

Back to the line of information processing, the dual-processing models reviewed in Section 2.1.1 also afford different lenses of heuristics, e.g., the peripheral route in the ELM model (Petty & Cacioppo 1986), the heuristic approach in the HSM model (Chaiken 1980, Chaiken & Eagly 1989), the associative evaluation in the APE model (Gawronski & Bodenhausen 2006), etc.

Although there do be different points in the above theories, they share a common assumption, that boundedly rational individuals take advantage of heuristics with high accessibility to conserve cognitive efforts. However, as pointed out by Shah & Oppenheimer (2008), heuristic effects detected in relevant research are mostly framed in specific decision tasks and to some extent cannot be regarded as common knowledge for understanding individual information processing; at the same time, how heuristics reduce the effort involved in judgement and decision processes is still a mystery.

2.2.3 Cognitive Biases

As argued by Tversky & Kahneman (1974), heuristic strategies, sometimes pretty useful, result in severe errors and systematic biases, e.g., non-regressive prediction, base-rate neglect, overconfidence, and overestimates of the probability of clues that easy to recall. Kahneman (2003) and Hilbert (2012) formally interpreted cognitive biases as the systematic departures of the beliefs that people establish and the choices they make from the optimal beliefs and choices normatively and logically predicted by the rational-agent models and the classical probability and utility theories. Hilbert (2012) synthesised eight cognitive biases into an integrative framework of noisy memory channels, and attributed these biases to the noisy information processing that reshape objective evidence (observations) into deviated subjective estimates (decisions). The very eight cognitive biases are conservatism, the Bayesian likelihood bias, illusory correlations, biased selfother placement, subadditivity, exaggerated expectation, the confidence bias, and the hardeasy effect. Baron (2007), in the book, *Thinking and Deciding*, investigated into more than 50 biases and heuristics. Besides, online Wikipedia tabulates more than one hundred biases of probability, belief and behaviour[2], and the list is still evolving.

Behind the voluminous labels of cognitive biases, there is almost a consensus that heuristics in information processing are the major driver for cognitive

[2]https://en.wikipedia.org/wiki/List_of_cognitive_biases

biases. A shallow manifestation of this consensus is the frequent parallel appearance of the two words, heuristics and biases. However, direct research concerning cognitive biases and heuristics primarily aimed at identifying the existence of different cognitive biases and heuristic effects through psychological experiments, and proving the outcomes of these biases and heuristics (Baron 2007, Hilbert 2012, Tversky & Kahneman 1974). How to precisely or quantitatively capture the heuristic strategies employed by boundedly rational individuals in judgement and choice settings and measure the effort saved and the biases incurred is still an open issue.

2.2.4 Information Distortion

In a narrow sense, information distortion refers to that individuals selectively sample information to favour their prior belief, preference, attitude, position, choice or dispositions before or during making a judgement towards a stimulus, while ignoring other unfavourable information. In a broad sense, information distortion means all kinds of information processing that deviates from the logical or accurate standards. Most of the direct research regarding information distortion, although limited, goes to the narrow sense, spotlighting the distorting procedure (Festinger 1957, Polman & Russo 2012, Russo et al. 1996, Russo et al. 2008). The broad sense is somewhat equivalent to biased information processing by accenting the distorted outcome (Brownstein 2003).

Russo et al. (2008) have hypothesised that information distortion is driven by three decision goals, i.e., to conserve the effort involving in elaboration, to increase the separation between different choices, and to attain consistency between the priors and the incoming stimulus. Drawing upon the delicately designed experiments with non-conscious priming, their research confirms that the goal of consistency accounts for the substantial part of information distortion. Their another investigation (Polman & Russo 2012) further establishes that, by technically increasing the participants' commitment to the prior preference, information distortion is enhance.

Collectively, as the parlance in section 1.2.1, studies surrounding information distortion accentuate the phenomena of selective attention (Best et al. 2005, Jonas et al. 2001, Lundgren & Prislin 1998), and the needs for cognitive consistency (Russo et al. 2008, Russo et al. 1996) in individual information processing from the perspective of cognitive dissonance (Festinger 1957), assuming that human systematically prefers to the information consistent with their own belief, attitude and decisions, at the same time ignores inconsistent information to reduce their cognitive dissonance (Elliot & Devine 1994, Festinger 1957, Lord et al. 1979, Polman & Russo 2012) (Brownstein 2003, for a review)(Hart, Albarracín, Eagly, Brechan, Lindberg & Merrill 2009, for a meta-analysis).

The current work generally follows the broad sense of information distortion, while substantially measuring distortion from the narrow perspective. The concept and measurement of information distortion will be revisited in Section 3.4.1.

2.2.5 Summary

Essentially, information distortion resultant from selective exposure to information, as well as cognitive biases as consequences of heuristics, can be attribute to individuals' goals of effort-saving or cognitive consistency (Russo et al. 2008, Shah & Oppenheimer 2008). However, few efforts have been dedicated to investigate the internal mental mechanisms and associated causal factors behind information distorting, biased processing and heuristics. As pointed out by Shah & Oppenheimer (2008), information distortion, biases and heuristic effects detected in relevant research are mostly framed in specific decision tasks and to some extent cannot be regarded as common knowledge for understanding individual information processing. How motivational and cognitive explanations of individual information processing can be combined to yield a more complete understanding of selective exposure to information, information distortion and biases, is an open issue for further exploration (Bohner & Dickel 2011).

As summarized above, substantial part of the studies regarding abnormalities in cognitive information processing underlined qualitative psychological explanations while somewhat ignored the quantitative measurements of distortion and biases. This treatment to some extent cannot precisely capture the details of how different factors lead to information distortion and cognitive biases.

2.3 Social Impact

The aforementioned studies pertaining to information cognitive processing, information distortion, and cognitive biases have largely ignored the influence of other individuals and groups in society in their theoretical building and empirical analyses. However, situating in a social context, individuals opinions are highly interdependent. They are, directly or indirectly, influenced by cultural norms, mass media and interactions in social networks (Mavrodiev, Tessone & Schweitzer 2013). In recent years, the ongoing growth of communication technologies has greatly facilitated the presence of social impact. Information cognitive processing is inevitably influenced by social factors. As claimed by Bagozzi & Lee (2002), "*social processes are important determinants of decision making for people*".

Research of social impact is rooted in social psychology. The earliest study could date back to the research of Triplett (1898) on the speed records of cyclists. He demonstrated the social facilitation effect using two laboratory experiments, which implied that the mere presence of others doing the same work facilitated task performance of the focal individual. After that, the studies of social impact in large measure defined social psychology and a sizeable compelling theories were established over the 20th century. The most well-known are the social comparison theory (Festinger 1954), the theory of normative and informative social impact (Deutsch & Gerard 1955), the social impact theory (Latané 1981), the social cognition theory (Bandura 1986). In the meanwhile, social psychologists found various effects of social impact,

including compliance and conformity (Cialdini & Goldstein 2004), majority and minority effect (Tanford & Penrod 1984), and resistance and polarization (Lord et al. 1979, Eagly & Chaiken 1993). Nowadays, scholarly concerns of social impact has extended to different disciplines, ranging from economics, politics, marketing, and opinion dynamics.

2.3.1 Perspectives in Social Psychology for Understanding Social Impact

This section outlines different theatrical perspectives dealing with social impact. The goal is to provide an extensive examination of theories of social impact in social psychology.

Social Comparison Theory

In his article, Festinger (1954) first used the term social comparison and proposed a systematic theory, with nine hypotheses, eight corollaries and eight derivations. The major idea of this theory is that people hold a drive to accurately evaluate his/her opinions and abilities and that they complete this evaluation by comparison with others in similar opinions and abilities in the absence of objective and non-social criteria. According to social comparison theory, a simple but powerful insight about how people evaluate themselves is that these evaluations often result from comparisons with others, especially the similar ones. Festinger (1954) also discussed the effects of discrepancy with respect to opinions and abilities between the referent person and the evaluating person. He presumed that people attempted to change ones own position or change referent persons position to reduce the discrepancy. People do not tend to evaluate his/her opinions or abilities by comparison with, however, others whose position are too divergent from themselves (Festinger 1954).

Shortly after publishing this article, Festinger (1957) diverted his attention away from social comparison theory and went on to theory of cogni-

tive dissonance. His social comparison theory, however, has interested numerous researchers and continues to be developed and advanced. Among these, the key advances were developments in understanding the motivations that underlie social comparison, and the particular types of social comparisons. Thornton & Arrowood (1966) posited two motivations accurate self-evaluation and self-enhancement operated in social comparison. Accurate self-evaluation was consistent with the original theory of Festinger (1957), which deals with the need to hold correct opinions and to have an accurate assessment of abilities. Self-enhancement deals with the positive affect or ego enhancement associated with being better off than others (Suls & Wheeler 2000). The motivation of self-enhancement was confirmed by another important work of social comparison, that is, the downward comparison theory proposed by Wills (1981). The main hypothesis of downward comparison is that people can increase subjective well-beings by comparing with someone less fortunate. When a person looks to another individual or group that they consider to be worse off than themselves in order to get a better feeling about their personal situation, they are making a downward social comparison. Wills (1981) also contended that people who are low in self-esteem, are more likely to make downward comparison because of their great need for self-enhancement. In contract to the downward comparison, when people compare themselves with an individual or group that they perceive as superior or better than themselves in order to improve their views of self or to create a more positive perception of their personal reality, they are making a upward social comparison. Both upward comparison and downward comparison are to seek self-enhancement. To keep a positive perception of themselves, people may distort, or ignore the information gained by social comparison, they may also choose to make upward or downward comparisons, depending on which strategy will further their self-enhancement goals.

Normative and Informative Social Impact

Deutsch & Gerard (1955) distinguished two broad forms of social impact,

normative and informative social impact and examined the effect of these two social impact upon individual judgement. Normative influence is "*an influence to conform with the positive expectations of another*", while Informational influence refers to "*an influence to accept information obtained from another as evidence about reality*" (Deutsch & Gerard 1955, p.629). Motivations for complying with normative expectations lie in the positive rewards or negative sanctions that might result from deviant behaviour (Price, Nir & Cappella 2006). Recognizing the prevalence of normative social influence in many decision situations, Fishbein & Ajzen (1975) incorporated subjective norm into their theory of reasoned action, attempting to examine the effect of normative belief and comply motivation on individuals attitudes, intentions and behaviours. By contrast, informational influence is based on the receiver's judgement of the relevant content of a message. It occurs where individuals have not enough information to arrive a decision. In nature, informational influence derived from the motive of accuracy and a desire to make a high quality decision (Kaplan & Miller 1987).

Social Impact Theory

The social impact theory proposed by Latané (1981) is the most popular theory for understand the nature of social impact. It attempts to describe how the mutual influences between individuals are affected by the time and space. Specifically, it posits social impact is mediated by three factors: the strength of the influence source, the distance between source and target, and the number of influence sources involved. Social impact theory provide a mathematical definition for understanding how individuals are influenced by other individuals or groups. According to this theory, the magnitude of social impact ($\hat{I}$), is a multiplicative function of the source strength(S), immediacy of the source and target (I) and the number of influence sources involved (N), which could be represented as the following formula, $\hat{I} = f(SIN)$. Further, social impact theory give a more precise description of the relationship between the number of influence sources and the impact magnitude,

$\hat{I} = sN^t, t < 1$, where the impact magnitude $\hat{I}$, is equivalent to a power function of the number of sources N. s represents the specific factors consistent in a given situation. Exponent t is presumed to be less than 1, which indicates that the marginal effect of additional influence source decrease. Empirical estimate of the average of exponent t is approximately 0.5 (Latané 1981).

Social Cognition Theory

Bandura (1986) systematically proposed social cognitive theory in his book *Social Foundations of Thought and Action: A Social-Cognitive Theory.* This theory is originated in social learning theory which illustrates how behaviour is acquired through watching the behaviour and consequences of others in the environment. Social cognitive theory expanded its precursor by arguing that the human behaviour is induced by the bidirectional and reciprocal interaction of internal personal factors in the forms of cognitive, emotional and biological events, environmental events and behaviour patterns (Bandura 1986). It is an overall framework for understanding human social behaviour, integrating a wide range of ideas, concepts and sub-cognitive process. Several basic conceptions about learning and behaviour constitute the basis of social cognitive theory, that is, observational learning/model, self-efficacy, self-regulation and triadic reciprocal determinism.

Observational learning asserts that people acquired new behaviours and skills through observations of behaviours and consequence of models. Behavioural mimicry and abstract modelling are two forms of observational learning. Behavioural mimicry implies that people witness and observe a behaviour conducted by models and then reproduce those actions. Abstract modelling is a high level form of learning, referring that observers extract the general rules embodied in the models behaviour and use these rules to guild future behaviour (Bandura 1986). Bandura (1986) underlines that observational learning is a universal and effective way for acquiring social behaviour.

Self-efficacy is another central and influential concept within social cognitive theory. Self-efficacy refers to "*peoples beliefs about their capabilities to*

exercise control over their own level of functioning and over events that affect their lives"(Bandura 1993, p.118). According to (Bandura 1993), self-efficacy partly determines choices of social context and activities. For example, individuals with high self-efficacy are more likely to resolve challenging problems and recover quickly from frustration and disappointments, while individuals with low self-efficacy tend to be less confident and to avoid challenging tasks. The social context and activities that individual involved, in turn, have an influence on the development of self-efficacy. It is in social context that people broaden and validate self-knowledge of their capabilities. Recognizing the central role of self-efficacy in behaviour performance, Ajzen (1991) incorporate perceived behaviour control into the theory of planned behaviour, combining with attitude and subjective norms to jointly determine intention and behaviour.

Self-regulation is a prominent aspect of social cognitive theory that illustrates the effect of self-generated influence on behaviour. It could mediate the effect of external influence and guild actions toward the anticipated consequence. As Bandura (1991)'s metaphor, without self-regulation, people would behave like a weathervane, consistently shifting directions to conform external social influence. Self-regulation is dependent on intentional and purposive activities where individuals are thought to manage their thoughts and actions in order to reach particular outcomes.

Triadic reciprocal determinism is the foundational hypothesis of social cognitive theory. It depicts how personal, behavioural, and environmental factors influence one another in a bidirectional, reciprocal fashion. With this hypothesis, Bandura (1986) goes beyond the traditional explanations of unidirectional causation in which behaviour is described as being shaped and controlled either by environmental influences or by internal dispositions.

2.3.2 The Effects of Social Impact

Individuals are motivated to form accurate perceptions of reality and react accordingly, to develop and preserve meaningful social relationships with oth-

ers, and to maintain a favourable self-concept (Cialdini & Goldstein 2004). Under these motives, social impact embodied in different effects, such as compliance with others beliefs and expectations, conformity to groups, majorities, authorities, and social norms, as well as resistance and counterargument, further lead to a variety of social phenomena, for example, polarization, social concerns and minority effects (Ahluwalia 2000, Ajzen 1991, Asch 1951, Deutsch & Gerard 1955, Fishbein & Ajzen 1975, Moscovici & Zavalloni 1969)(Cialdini & Goldstein 2004, for a review).

Compliance and Conformity

Cialdini & Goldstein (2004) argued that compliance and conformity are two major effects of social impact, and identifies the underlying motives that drive compliance and conformity behaviour respectively.

Compliance refers to a disposition or tendency to yield to the will of others' requests. The requests may be explicit (i.e. a door-to-door campaign for charitable donations) or implicit (advertising)(Cialdini & Goldstein 2004). (Cialdini 1987) initially identifies six psychological principles that could be used to facilitate individuals compliance, that is, authority, social proof, scarcity, liking, reciprocation, and consistency and commitment. Based on these psychological principles, he further propose three motives, to be accurate, to affiliate and to maintain a positive concept, that drive compliance behaviour of individuals (Cialdini & Goldstein 2004). The authority, social proof and scarcity correspond to the motive of accuracy, the liking and reciprocation serve as the motive of affiliate, and the consistency and commitment is accordance with self-concept.

Conformity refers to the tendency to change individuals perceptions, opinions or behaviours in ways that match the responses of others (Cialdini & Goldstein 2004). The line experiment Asch (1956) started up a field of research in conformity. Since then, many studies investigated the circumstances that give raise to conformity and the factors that underlie conformity. Factors, such as age (Walker & Andrade 1996), gender (Eagly & Carli 1981),

group size and culture (Bond & Smith 1996), as well as type of stimulus material (Crutchfield 1955) have been demonstrated to determine the level of conformity. Drawing on informational and normative conformity (Deutsch & Gerard 1955), Cialdini & Goldstein (2004) argued that in addition to the accuracy motive deriving from informational conformity and affiliation motive deriving from normative conformity, there exists another motive underlying conformity, maintaining a positive self-concept. Both accuracy motives and affiliation motives help to maintain a positive self-concept.

Another special effect of conformity can be attributes to Keynes (2006), the most influential economist. Keynes (2006) metaphorized professional investments into the a newspaper competition setting where "*the competitors have to pick out the six prettiest faces from a hundred photographs, the prize being awarded to the competitor whose choice most nearly corresponds to the average preferences of the competitors as a whole; so that each competitor has to pick, not those faces which he himself finds prettiest, but those which he thinks likeliest to catch the fancy of the other competitors, all of whom are looking at the problem from the same point of view*". The metaphor portrays the principle of convention, which each member in a specific society follow to behaviour in line with the perceived consensus of other people.

Majority and Minority Impact

Up to the date of 1960s, many studies of conformity and compliance revealed that it was minority who were confirming to the majority. However, Moscovici & Personnaz (1980) posited a different line. In his well-known green/blue experiment, he showed that minority were influential because they elicited informational conflict and challenged recipients' understanding of issues. This is known as minority influence, revealing the phenomena of "*few can influence many*".

Latané & Wolf (1981) proposed a general social impact model for both minority and majority sources. It predicts that as the size of the majority grows, the influence of the minority decreases, across the public and private

settings. A meta-analysis conducted on 97 minority influence experiments. Wood, Lundgren, Ouellette, Busceme & Blackstone (1994) showed that majority sources were more likely to exert influence through normative pressure, whereas the minority sources always took the approach of informational influence. Moreover, inspired by dual-process theory of information cognitive processing, Dickel & Bohner (2012) claimed that minority influence can be seen as similar to systematic processing of the heuristic-systematic model (Chaiken & Eagly 1989) and central route of the elaboration likelihood model (Petty & Cacioppo 1986), both of which required the careful scrutiny of influence information. Also, low-effort compliance and conformity with majority is comparable to the heuristic processing in the heuristic-systematic model and the peripheral route of the elaboration likelihood model.

Resistance and Polarization

In the research stream of persuasion and attitude change, researchers found people holding strong attitude are likely to resist counterattitudinal information (Fishbein & Ajzen 1981, Pomerantz, Chaiken & Tordesillas 1995). As a result, the persuasion appeals may not change targets attitudes but rather lead to an increase in polarization (Lord et al. 1979). Fishbein & Ajzen (1981) outlined three mechanisms of resistance: biased assimilation, relative weighting of attributes, and minimization of spillover. Biased assimilation refers to individuals' tendency to evaluate attitude-consistent information as more valid than attitude-inconsistent information. It is a well-finding that have been clarified by many literatures (Lord et al. 1979, Ditto, Scepansky, Munro, Apanovitch & Lockhart 1998). Relative weighting of attributes refers to the tendency of individuals to carefully considerate the implications and the relative importance of the persuasion information. People may accept the validity of the information but deny its implications or its importance in order to keep their own attitude. Minimization of spillover refers that individuals ignore the causal or correlational relationship among different attributes to discount the effect of persuasion information. Ahluwalia (2000) further

examined the role of refutability of the persuasion information in influencing use and effectiveness of the three resistance mechanisms with empirical research in the context of a field study and a lab experiment. It is showed that biased assimilation and relative weighting were sensitive to the refutability of the persuasive communication but not the minimization of spillover.

The biased cognitive processing and resistance cause attitude to polarize. In turn, attitude polarization may lead to greater resistance to counterattitudinal information (Eagly & Chaiken 1993). Tormala & Petty (2002) proposed a metacognition framework to account for resistance to persuasion. They demonstrated that when people resist persuasion, they can perceive this resistance, reflect on it, and become more certain of their initial attitudes. Resistance strengthen initial attitude and this effect is mediated by source credibility (Tormala & Petty 2004).

2.3.3 Dynamics and Evolution of Social Impact at the System Level

Research of social impact in social psychology provides better understanding in how basic human social motives simulate attitude and behaviour change. However, due to the methodological constraints, it is limited to the perspective of individual-level cognition, but fails to build a conjunct observation with system level. As claimed by Mason et al. (2007), although controlled laboratory studies of psychology could profoundly explain the unique causal inferences between social impact and information cognitive processing, the method is less informative when multiple sources and multiple targets of impact interact in a large scale over time.

Since the end of last century, benefiting from the advances in computer power and simulation techniques, researchers from multi-fields (especially the communities of sociophysics and complex science), have paid a fair amount of attention to the issue of opinion dynamic of social impact from aggregated level. They developed lots of influential models, for example, the model of majority rule voting (Galam 1990), dynamic social impact (Nowak

et al. 1990), culture dissemination (Axelrod 1997), opinion evolution (Sznajd-Weron & Sznajd 2000), bounded confidence (Deffuant et al. 2000, Hegselmann & Krause 2002), and continuous opinions and discrete actions (Martins 2008). By simplifying individual's attitude system and social interaction, those opinion dynamic models grasp some essential and surprising mechanism of social impact. They are generic and allow to describe and explain the collective phenomena emerging from the interactions of individuals within the social network.

Majority rule is a decision rule that the majority opinion is taken by all agents. Galam (1990) firstly took the idea of majority rule to study bottom-up voting in hierarchical structures. It is showed that under the majority rule, the number of hierarchical level imposes strong restrictions on the populations representation power in the top leadership. In particular, 70% of populations were shown self-elimination within six hierarchical steps (Galam 1990). Galam (1999), Galam (2000) and Galam (2008) discussed the applications of this model for understanding the historical event of eastern European communist collapse and the difficulty in changing leaderships in well-established institutions.

Arguing that social impact theory proposed by Latané (1981) is a static theory concerning how social environment operates at individual level and a given point in time, Nowak et al. (1990) proposed a dynamic social impact theory. This theory uses the basic tenets of social impact theory, mainly that the magnitude of social impact experienced by individual is a function of strength, immediacy, and number of impact sources. As suggested by its name, dynamic social impact theory considers the reciprocal influence among individuals and its ongoing group process extending over time. Two indicators of strength were distinguished, persuasiveness-the ability to persuade people with opposing beliefs to change their minds, and supportiveness-the ability to provide social support to people with similar beliefs (Latané 1981). Specifically, it assumes that impact magnitude is the average force (persuasiveness/supportiveness divided by the square of the

distance) exerted by each group member multiplied by the square root of the number of group members (Nowak et al. 1990). The formula has the form: $\hat{I} = N_0^{1/2}[\sum(S_i d_i^2)/N_0]$, where $\hat{I}$ denotes persuasiveness or supportiveness impact, N_0 the number of sources, S_i the persuasiveness or supportiveness of source i, and d_i the distance between source i and the recipient. The idea that impact magnitude decrease as the square of the distance implies that individual is more influenced by close neighbors than by individuals far away. The results caused by this assumption with simulation, have showed that minority opinions could survive and clustering despite the greater numbers of the majority (Mason et al. 2007).

Axelrod (1997)'s culture dissemination model is a prominent model of dynamic social impact. In this model, the word *culture* refers to "*the set of individual attributes that are subject to social influence*"(Axelrod 1997, p.204). This definition differentiate itself from opinion dynamics where opinion is considered as a scalar variable (Castellano, Fortunato & Loreto 2009).The model builds on a self-reinforcing mechanism of 'more interaction' - 'more similarity', that is, people are more likely to interact with others who share similar cultural attributes, and interactions itself tend to increase the number of cultural attributes they share.

Opinion evolution model proposed by Sznajd-Weron & Sznajd (2000) was supposed to describe the influence of agents of a pair on the decision of its nearest neighbours. It assumes that agents of a pair with same opinion will convince their nearest neighbours to agree with this opinion. By contrast, agents of a pair with different opinions will imposes its opinion on the other agents nearest neighbour. This model is also known as USDF model since it is consistent with a proverb: "united we stand divided we fall" (Sznajd-Weron & Sznajd 2000).

Bounded confidence model proposed by Deffuant et al. (2000) is a most popular model of continuous opinion dynamics. In this model, at each time step, a randomly selected agent can only interact with another agent whose opinion lies in an interval, around its own opinion. If an agents opinion

exceeds this interval, the interaction will not happen. If instead, both of the agents will adjust their positions to get closer to each other. In reality, individuals always exchange opinions with many compatible neighbours at a time, but rather with one of its compatible neighbour, like in the settings of Deffuant et al. (2000). The model proposed by Hegselmann & Krause (2002) is quite similar to bounded confidence model. The difference exists in the update rule: the randomly selected agent interact with all of its compatible neighbours at each time step (Castellano et al. 2009).

It is interesting that two people may choose the same alternative but their individual attitudes towards that alternative may be different in a binary decision. In most cases, peoples action is only a projection of his/her actual opinion. Martins (2008)'s continuous opinions and discrete actions model combined the external binary opinion (action) and internal opinion. This model makes it possible to model the opinions of agents as continuous functions even when the observed actions are binary (Castellano et al. 2009).

2.3.4 The Role of Social Structure

Structure of social relation determines who influence whom. It necessarily occupies a role in the process of social impact. How social network structure affects the diffuse of opinions/behaviours across a population has been extensively studied in complex system (Altafini 2012, Centola 2010, Sueur et al. 2012). Various social structure features were identified, such as connection mode, heterogeneous and dynamic characteristics. Researchers measured dissemination path of opinions/behaviours, and convergence and polarization effect under particular initial opinions distribution with various social structure features.

The individuals and their relationships could be represented in an abstracted graphic fashion by a set of nodes and edges. The nodes represent individuals, while the edges indicate the information transmission and interaction relationship between two individuals. Scholars have devoted to explore the opinion formation and social dynamics from the perspective of

social network interaction and evolution. They found that a large number of real networks are neither completely regular (e.g., Euclid grid) nor completely random (deciding the existence of an edge between two individuals according to a probability), but are complex networks endowing statistic characteristics which lie somewhere between these two extremes. Researchers have recognized different class of complex network, such as small world network (Watts & Strogatz 1998) and scale-free network (Barabási & Albert 1999).

- **Small world networks**. Watts & Strogatz (1998) built a small world network that captures both the properties of regular lattices and random graphs. Most pairs of nodes in this network are not only highly clustered, like regular lattices, but also connected by a short path, like random graphs. This model is inspired by Milgram (1967)'s letter delivery experiments, in which a small-world effect was firstly demonstrated. Further, Watts & Strogatz (1998) speculated that small world networks would display enhanced propagation speed and synchronizability, as compared with regular lattices. Since its inception, this model tempts researchers in a variety of fields, such as computer scientists (Kleinberg 2000), epidemiologists (Wallinga, Edmunds & Kretzschmar 1999) and statistical physicists (Barthélémy & Amaral 1999)(Strogatz 2001, Newman 2003, for reviews). The notion of small-world effect has been extremely influential in many disciplines.

- **Scale-free networks**. In most real world networks, the number of nodes is not fixed, but evolving, with addition of new nodes that are connected to the already existing nodes. The Scale-free networks is such a growing network proposed by Barabási & Albert (1999). In this model, each new node entering in the network accord to preferential attachment rule (e.g., prefer to create links with high-degree nodes) to establish relationships with already existing nodes. The network obtained by this way have a power law degree distribution $P(k) \sim k^{-r}$ with $r = 3$. where k indicates the degree of nodes (Castellano et al. 2009). Scale-free networks refer to a class of networks with power law degree

distributions. Research of Yu & Van de Sompel (1965) on the citation network of scientific papers was probably the first study demonstrating a scale-free network in the real world. It was found that a new article tended to attach themselves to high-degree article rather than less connected ones. Many other real networks, such as metabolic reaction networks (Jeong, Tombor, Albert, Oltvai & Barabási 2000, Jeong, Mason, Barabási & Oltvai 2001), World Wide Web (Albert, Jeong & Barabási 1999), semantic networks (Steyvers & Tenenbaum 2005), and interbank payment networks (De Masi, Iori & Caldarelli 2006) were found to be in accordance with the scale-free network. Albert, Jeong & Barabási (2000) suggested that the scale-free network has some functional advantage. Since the distribution of nodes degree is very asymmetry, such networks could be resistant to random failures.

To sum up, the social structure shown in different types of network models has strong influence on individuals information cognitive process and opinion dynamics. As appealed by Sobkowicz (2009), the need for establishing models of opinion dynamics and network structure as realistic as possible is a central issue for observing dynamics and evolution of social impact at the system level.

2.4 Summary

This chapter scrutinises the mass of literature from three major lines. The first line is information cognitive processing and attitude shaping, covering the major aspects such as the processes of information elaboration and the associated influencing factors, the motivations involved in different routes of information processing, the discrepancy processing and counterarguing, metacognitive elements such as confidence, and cognitive processing in sequential exposure settings. The second line concerns the *abnormalities* in information processing. Several correlated concepts including bounded rationality, heuristics, cognitive biases and information distortion are clarified.

The third line marshals the cross-discipline views associated with social impact. These reviews equips the current research with a wealth of fundamental knowledge, and substantially scaffolds the subsequent investigations.

Chapter 3

Attitudes, Distortion and Biases: Conceptualisation and Measures

To fathom the mystery of distortion and cognitive biases in individual information processing under social impact, it is necessary to rethink and theoretically clarify the nature of several critical concepts and design their measures, on the basis of the literature review in Chapter 2. These concepts surround attitude, cognitive dissonance, information distortion and cognitive bias, which are mathematically pictured in this chapter. By rethinking these concepts and developing their measures, this chapter aims at building a scaffolding for the empirical analysis and social computing of the current research to unravel the interactive relationships among these attitude-relevant constructs both in the individual level and in the societal level.

3.1 Attitude

In psychology, an attitude is an combination of an individual's evaluative judgements, reflected in affective, cognitive and behavioural responses, about a given object (e.g., a person, place, thing, or event)(Crites, Fabrigar &

Petty 1994). The sense of attitude in the context of information cognitive processing comes from two different but correlated entities, i.e., the attitude advocated by a persuasive message (expressed verbally or in written or coded forms by a specific sender through channels such as media or interpersonal conversations), and the attitude that maintained by an individual (or recipient) exposed to the message.

3.1.1 Message Attitude

The attitude communicated in a persuasive message is the evaluative judgements of the message sender. From the perspective of an individual who is exposed to a message, the attitude conveyed by the message has two dimensions. The first dimension is the *objective* or true attitude advocated by the message (or actually, the sender). It is the original value orientation that the arguments and cues marshalled in the message attempt to share with or sell to the audience. The second dimension is the *subjective* attitude perceived by the individual who receive the message. It is the attitudinal sense that the receiving individual captures and makes during their cognitive processing of the message, and is the mapping of the objective message attitude on their cognitive space. Due to the bounded rationality of the receiving individual, the perceived attitude always deviates from the objective attitude implied in the message. This deviation also belongs to the category of information distortion and cognitive bias that the current research tries to apprehend.

3.1.2 Individual Attitude

Individual attitude indicates the affective, cognitive and behavioural inclinations of an individual to a specific topic or advocacy. In the situation of information cognitive processing, the attitude of an individual demonstrates the procedural psychological status of the individual before being exposed to a message, during the processing of the message, and after the message processing. Two important attitudinal exhibitions along with this

course are sampled, i.e., *prior* attitude and *posterior* attitude(Burnstein & Vinokur 1977). Prior attitude is the attitude maintained by an individual prior to the exposure of an advocacy-relevant message. Posterior attitude records the attitude that the individual shapes after processing and judging the message, conditioned by their personal traits and the degree of elaboration.

3.1.3 Attitude Measure

An attitude is an composite indicator with multiple components. The first component is the attitudinal valence (tendency or direction), e.g., favour vs. disfavour, like vs. dislike, agree vs. disagree, etc. The second component is the attitude strength, i.e., the exact value point of attitude within the continuum from one valence side to the opposite side, e.g., from strongly favour to strongly disfavour. The third component characterises the confidence or certainty as a metacognition in the declared attitude(Petty et al. 2002). With regard to the measurement of attitude, Carpenter & Boster (2013*a*), Carpenter & Boster (2013*b*), Petty et al. (2002), Russo et al. (2008) and (van Strien, Kammerer, Brand-Gruwel & Boshuizen 2016) combined attitude strength and attitude confidence in their investigations.

It could be too complicated to separate attitude strength and confidence and examine respectively their interactions with other variables, especially when information distortion and cognitive biases must be inferred from these attitudinal components. Thus, the present research regard attitude as a holistic indicator transformed from the reported attitude strength and attitude confidence as follows:

$$att_{comput} = att_{report} - (att_{report} - att_{neutral}) \cdot log_3 \frac{1 + (conf_{max} - conf_{report})}{conf_{max} - conf_{min}} \tag{3.1}$$

where att_{comput} is the computed attitude value, and att_{report}, $att_{neutral}$, $conf_{report}$, $conf_{max}$ and $conf_{min}$ denote respectively the reported attitude, the neutral

Table 3.1: Attitude Adjustments as per Reported Attitude and Confidence

Adjusted Attitude / Reported Attitude; Reported Confidence		**7**	**6**	**5**	**4**	**3**	**2**	**1**
7	**Very confident**	7.00	6.00	5.00	4.00	3.00	2.00	1.00
6	**Fairly confident**	6.58	5.72	4.86	4.00	3.14	2.28	1.42
5	**A bit confident**	6.21	5.48	4.74	4.00	3.26	2.52	1.79
4	**Neither confident nor unconfident**	5.89	5.26	4.63	4.00	3.37	2.74	2.11
3	**A bit unconfident**	5.61	5.07	4.54	4.00	3.46	2.93	2.39
2	**Fairly unconfident**	5.34	4.90	4.45	4.00	3.55	3.10	2.66
1	**Very unconfident**	5.11	4.74	4.37	4.00	3.63	3.26	2.89

attitude, the reported confidence and the maximum and minimum confidences.[1]

Table 3.1 illustrates the outcomes of the above mapping when attitude and confidence are reported as per a Likert 7-point scale.

The logic behind the above calculation is essentially to smooth the reported attitude strength according to the reported confidence, without changing the overall attitude valance/direction. For instance, when an individual declares an attitude strength with 6 (e.g., fairly favour) and a certainty score with 5 (i.e., a bit confident), the actual attitude of the individual is 5.48, i.e., a stance slightly less than 6 but still greater than the neutral point 4 (namely, the attitude valance is still the same); whereas when an individual

[1]In the empirical study of Chapter 4, for the objective attitude of a message, the *reported* attitudes and confidences are the scores that invited experts rate in a specially designed pilot experiment; for the prior attitude, posterior attitude and perceived message attitude of individuals who participated in the experiments, the *reported* attitudes and confidences are their scores in response to the corresponding instrument items.

reports an attitude strength with 1 (e.g., strongly disfavour) and a certainty score with 3 (i.e., a bit unconfident), the actual attitude is 2.39, i.e., a stance greater than 1 but still less than the neutral point.

For simplicity, Table 3.2 gives the symbols associated with attitude-relevant measures.

When no distortion or bias occurs in an individual's processing of the incoming message, the attitude outcome could be the average (i.e., the neutralisation) of the prior attitude of the individual and the message attitude. Hence, in order to measure distortion and biases, an unbiased attitude $\bar{A}_t$ is introduced.

Since message attitude has two dimensions, i.e., the objective attitude stemming from the sender's persuasive attempt ($\check{A}_m$) and the attitude perceived by the receiving individual (A_m), the unbiased attitude, $\bar{A}_t$, can be correspondingly defined in the following two ways:

$$\bar{A}_t = \frac{A_{t-1} + A_m}{2} \tag{3.2}$$

or

$$\bar{A}_t = \frac{A_{t-1} + \check{A}_m}{2} \tag{3.3}$$

For the current research, when it comes to information distortion, the first way is adopted; whereas when cognitive biases are considered, the second way is followed. The reason will be discussed in the final part of Section 3.4.1.

The current research involves complex comparisons between different attitude-relevant measures. These measures are mapped onto a continuous scale (whose length is s). So what level of difference on this scale can be considered significant? This is really a subtle issue. Technically, this issue is resolved in the current research by reduction, i.e., partitioning the attitude scale into eight uniform segments, as depicted in Figure 3.1. A difference or change shorter than one segment can be regarded as trivial, a difference or change longer than one segment but shorter than two segments is a slightly

Table 3.2: Symbols Associated with Attitude-Relevant Measures

Symbol	**Description**
advocacy	An advocacy or topic.
i, j	The ith and jth individual.
$t-1$, t	Time points. t is the current time, and $t-1$ is the prior time.
att_{t-1} or A_{t-1}	The prior attitude of an individual, smoothed as per Equation 3.1
m	An advocacy-relevant message an individual is exposed to at time t.
att_m or A_m	The attitude of message m perceived by an individual, smoothed as per Equation 3.1
$\check{att}_m$ or $\check{A}_m$	The objective or true attitude implied in message m, smoothed as per Equation 3.1.
$deviat_t$	The deviation of an individual's attitude perception with regard to message m from the objective attitude of m.
$\bar{att}_t$ or $\bar{A}_t$	The theoretical unbiased attitude that an individual shapes from unbiased cognitive processing of message m.
$disson_t$	The cognitive dissonance or inconsistency that an individual experience during the processing of message m.
att_t or A_t	The posterior attitude that an individual develops after processing message m, smoothed as per Equation 3.1.
s, $start$, end	The length, minimum and maximum value of the scale for attitude relevant measures. The length $s = end - start$. $start + s/2$ is the neutral point. An attitudinal value greater than $start + s/2$ represents a positive valance (e.g., favour, like, agree, etc.), whereas an attitude less than $start + s/2$ implies a negative response (e.g., disfavour, dislike, disagree, etc.).
$valance(A)$	The valance of attitude A.
δ	The signal relationship (i.e., $+1$ or -1) between an individual's prior attitude (A_{t-1}) and the perceived message attitude (A_m).
$distort_t$ or D_t	The amount of information distortion during an individual's processing of message m.
$bias_t$ or B_t	The amount of cognitive bias during an individual's processing of message m.

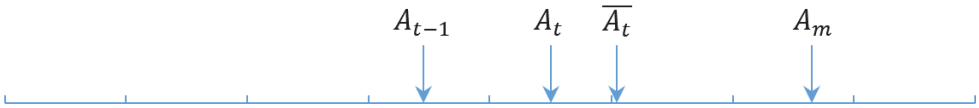


Figure 3.1: The Scaling and Labelling of Attitude

significant one, whereas a difference or change longer than two segments declares a significant effect. This treatment is proved substantially effective. At the same time, it greatly smooths the understanding of the measures in later sections, especially information distortion.

On the scale line in Figure 3.1, attitude-relevant measures such as A_{t-1}, A_m, $\bar{A}_t$ and A_t are also labelled, as an example.

The signal relationship, δ between the individual's prior cognition (A_{t-1}) and perceived attitude of the message (A_m) is indicated by:

$$\delta = \begin{cases} 1 & A_{t-1} \geq A_m \\ -1 & A_{t-1} < A_m \end{cases} \tag{3.4}$$

3.2 Perceived Message Attitude Deviation

The deviation of an individual's attitude perception with regard to an incoming message from the objective attitude communicated in the message is introduced as a criterion to decide whether a perception bias produces. This perception bias may works as a precursor of information distortion and cognitive biases, as will be explored in the empirical study in Chapter 4. It is measured as follows:

$$deviat_t = \frac{A_m - \check{A_m}}{s} \cdot 8 \tag{3.5}$$

Here, the difference between the individual's perception (A_m) and the objective attitude of the message ($\check{A_m}$) is granulated by dividing $s/8$, which is the unit length of each segment of the attitude scale (see Figure 3.1).

Given the meaning of the length of one segment, as discussed in Section 3.1.3, $|deviat_t| < 1$ indicates a insignificant deviation, $1 \leq |deviat_t| < 2$

means weak but still a bit significant deviation, whereas $|deviat_t| \geq 2$ indicates a significant deviation.

Intuitively, the more significant the deviation of the attitude an individual perceives from an incoming message from the objective message attitude, the more substantial cognitive biases will be yielded. This leads to the hypothesis regarding the linkage between the constructs of perceived message attitude deviation and cognitive biases for the current research.

3.3 Cognitive Dissonance

Cognitive dissonance is also referred to as cognitive inconsistency, evolving from the seminal and influential theory of cognitive dissonance (Festinger 1957). According to Festinger (1957) and Festinger (1962), cognitive dissonance indicates a state of mental stress or discomfort suffered by an individual who holds two or more elements of cognition (e.g., belief, knowledge, idea, or value) that are relevant to each other but incompatible with one another, or undertakes an action that is contradictory to one or more elements of cognition, or is exposed to new information that conflicts with existing cognitions. When experiencing this unpleasant state, an individual will make corresponding attempts to reduce or eliminate the dissonance. The individual may change one or more of the elements of cognitions involved in the dissonance, or acquire new information or beliefs that will raise the existing consonance and thus mitigate the total dissonance, or selectively disregard or reduce the importance of those dissonant cognitions(Festinger 1957). In the settings of information cognitive processing, the state of dissonance reflects the aroused psychological conflict when an individual's initial attitude does not match the attitude advocated by the incoming message. In this spirit, the magnitude of cognitive dissonance, $disson_t$, can be measured by the distance between an individual's prior attitude, A_{t-1} and the perceived

message attitude, A_m, as follows:

$$disson_t = \frac{A_{t-1} - A_m}{s} \cdot 8 \tag{3.6}$$

In a like way, $|disson_t| < 1$ can be interpreted as no significant cognitive dissonance or inconsistency being aroused, $1 \leq |disson_t| < 2$ means weak dissonance or inconsistency, whereas $|disson_t| \geq 2$ reflects strong dissonance or inconsistency.

The above measure will be revisited in Section 5.1.1.

A bulk of literature has established the relationship between cognitive dissonance and information distortion. According to Festinger (1957), when experiencing the unpleasant state of dissonance, an individual will make corresponding strategies to reduce or eliminate the dissonance. The first kind of strategies an individual may take is to adjust one or more of the elements of cognitions involved in the dissonance. The second kind of attempts is to acquire new information or beliefs that reasonably explain the prior cognitions and therefore raise the existing consonance and thus mitigate the total dissonance. The third one is to selectively disregard or reduce the importance of those dissonant cognitions. The first strategy is virtually a persuading attempt try to achieve, but sometimes it just does not happen. The latter two strategies are essentially information distortion, as defined in Section 1.1, that an individual systematically prefers to the information consistent with their own belief, attitude and decisions, at the same time ignores inconsistent information to mitigate their cognitive dissonance(Brownstein 2003, Elliot & Devine 1994, Festinger 1957, Lord et al. 1979, Polman & Russo 2012). According to the elaboration likelihood model (ELM)(Petty & Cacioppo 1986), an individual may overrate the elements in an input message consistent to existing cognitions and suppress those inconsistent elements in a distorted way. The heuristic-systematic model (HSM) advocated by Chaiken & Eagly (1989) postulates that an individual may follow the principle of least effort to defend existing attitude. In a like manner, the cognitive energetic theory proposed by Kruglanski et al. (2012) includes cognitive inertia in maintaining existing

consonance as a restraining force for an individual's cognitive processing. In the disconfirmation model, Edwards & Smith (1996) suggested the term *prior belief effect* to describe the phenomena that people evaluate information compatible to their prior beliefs more stronger than incompatible information. Investigations of Russo et al. (2008) confirm that in order to allay cognitive dissonance, individuals often distort received information with conflicting elements to favour their prior attitudes or preferences. According to Hart et al. (2009)'s meta-analysis, humans are almost two times more likely to select information that supports their prior attitudes. Knobloch-Westerwick, Mothes, Johnson, Westerwick & Donsbach (2015)' identified confirmation effects in political information processing scenarios and in contrast attitude-congruent exposure reinforces attitudes whereas attitude-discrepant exposure impairs attitudes. A recent research by van Strien et al. (2016) reports that when processing and evaluating information from different Internet websites, those individuals with stronger prior attitudes recalled more information from the websites which manifesting congruent stances, and scored lower credibility to those websites with conflicting stances.

The above knowledge on the one hand founds the hypotheses in Chapter 4 and the model at individual level in Chapter 5, concerning the interactions between cognitive dissonance and distorted or biased information processing, and on the other hand presents the logic of measuring information distortion in next section.

3.4 Information Distortion and Cognitive Biases

3.4.1 A Rethinking

Russo et al.(Russo et al. 2008, Polman & Russo 2012) measured information distortion in a sequential exposure setting where individuals were given six pieces of information relevant to a judgement task one by one. The goal of

the judgement task is to choose a restaurant from two alternatives. Each piece of information describes a different aspect for evaluating the restaurants. One piece of information is technically designed by the researchers to favour one of the restaurants, another piece is set to favour the alternative restaurant, whereas the other four pieces are neutral without any stand. The six pieces of information were marshalled as follows: the two pieces of information with their own orientations were offered in the first and fourth places respectively, and the other neutral pieces were randomly presented to participants in the other places. The measurement seeks to capture the overall degree that an individual distorts each presented piece of information to defend the developed preference (for the previously chosen restaurant). The following computation gives the overall information distortion (D) made by a specific individual:

$$D = \frac{\sum_{i=1}^{n} (|f_i - 5| \cdot \delta_i)}{n} \tag{3.7}$$

where n denotes the total pieces of information presented (i.e., 6), and f_i stands for the individual's subjective estimation of the orientation of the ith piece of information, whose value ranges within a $[1, 9]$ scale, with 5 being the neutral position, $[1, 5)$ favouring the first restaurant, and (5,9] favouring the alternative restaurant. The δ_i is a decision function defined as follows:

$$\delta_i = \begin{cases} 1 & i = 1 \\ 1 & i > 1 \; and \; valance\,(f_i) = valence\,(p_{i-1}) \\ -1 & i > 1 \; and \; valance\,(f_i) \neq valence\,(p_{i-1}) \end{cases} \tag{3.8}$$

where p_{i-1} is the stand of the individual before being exposed to the ith piece of information, mapped to the same scale to f_i.

The present research acknowledges the insights provided by the treatments of Russo et al.(Russo et al. 2008, Polman & Russo 2012). However, one issue should be pointed out with their measure. They technically quantified information distortion as the difference between an individuals' perception of the position attached to the presented pieces of information and the neutral

value, adjusted by the signal direction of their current perception relative to their previous preference. According to the concept of information distortion, distortion manifests the multi-lateral relationships among individuals' prior preference, their perception of the incoming stimulus, and their posterior preference. If there is no distortion, individuals integrate their knowledge regarding the stimulus into their prior preference, and shape a new preference as a *balance* or *compromise*. Therefore, the amount of information distortion calculates the difference between the posterior preference and the theoretical balanced position. The balanced position is the neutralisation of individuals' prior preference and their perception of the incoming stimulus, considering the direction of the posterior preference moving towards or away from the perceived position of the stimulus. This neutralised value is not necessarily equal to the neutral value of the scale.

Moreover, we need to distinguish four rubrics of information distortion as follows:

- **Intentional distortion**. Individuals deliberately distort the input information to defend the developed mentalities or to achieve cognitive consistency, as illustrated above. The basic assumption behind this distortion is that individuals possess the faculties to discern and do successfully learn the orientation of an incoming information, but still distort the information in a biased way to persist their own position even the information is delicately designed to sway them into an opposite direction.

- **Heuristic distortion**. Individuals employ heuristic strategies to reach a fast decision, and therefore to conserve efforts in managing errors. They may be unaware of the strategies they take. But sometimes they are conscious of their behaviour, but just don't want to make a correction to pursue accuracy. Drawing upon the heuristics, their evaluation of the received stimulus may depart from the *objective* points implied in the stimulus, but they come up with a decision just as per the inaccurate judgement.

- **Unavoidable distortion**. When individuals are incapable to make sense of the incoming information, the way we measure intentional distortion may fail to capture the real distortion individuals make. There are definitely conditions that individuals cannot make accurate evaluation, due to their mental limitations, but even in these conditions, they also think they are right. In other words, when individuals take every possible effort to scrutinise and assess the incoming information, and they draw a further conclusion based on this assessment even it is inaccurate, how could we say individuals are distorting the information presented? Or even there is distortion, it is just unavoidable distortion. Another kind of unavoidable distortion is attributed to environments (Simon 1955, Simon 1956). For example, if a person has to find out the best choice between multiple options, with each leading to a payoff in a certain probability. Suppose they don't have any prior knowledge regarding the payoffs and the probabilities, and cannot sample the information from the environment at the beginning. Before they arrive at the optimal solution, they have to acquire the knowledge and update their beliefs by trial and error. In each round of trial and error, the incomplete samples may equip them with an inaccurate probabilistic estimate, which in turn biases their decision from the rational one. In this case, individuals can draw accurate statistics from the data but being naive about the potential biases in the data provided by environments (Le Mens & Denrell 2011). Nevertheless, this unavoidable distortion can still be interpreted as the outcome of the limitations of resources that an individual possesses to interact with the environment, according to viewpoints of flawed information processing of human minds.

- **Distortion as artefacts**. As argued by Haselton et al. (2005), some cognitive biases are just artefacts of research strategies or experimental settings, which cannot repeat the way that human minds are inherently designed. This distortion is beyond the discussion of the current research, but we should bear it in mind to avoid it in our research

Table 3.3: Rubrics of Information Distortion

Distortion Manifest-ation \ Distortion Rubric	Intentional distortion	Heuristic distortion	Unavoidable distortion	Distortion as artefacts
Successfully learns the objective value in an incoming information (i.e., no significant deviation between perceived value and the objective value, or $\|deviat_t\| < 2$)	✓	×	×	-
Cognitive dissonance aroused ($\|disson_t\| >= 2$)	✓	May or may not	May or may not	-
Judgement anchors	Prior value and perceived value	Perceived value and may also prior value as a heuristic	Perceived value	-
Goals or motivations	Effort saving, cognitive consistency	Effort saving, heuristics	Accuracy	-
Distorts information presented	✓	May or may not	Actually not	-
Makes biased judgements	✓	✓	✓	✓
Be aware of the biased judgements	✓	May or may not	×	-

design.

Table 3.3 further summaries the differences (and also overlaps) among the above rubrics of information distortion.

From Table 3.3, the boundaries at least among intentional distortion, heuristic distortion and unavoidable distortion can be distinguished.

It is sensible to capture intentional distortion, supposing that individuals are willing to objectively report their subjective perception of the information presented, in a like manner to the research of Russo et al.(Russo et al. 2008, Polman & Russo 2012). However, heuristic distortion and unavoidable distortion are just subtle for direct empirical calibration. Alternatively, we regard the *objective* position of a stimulus as the optimal or rational evaluation of the stimulus, and gauge the deviation of individuals' posterior opinion from this rational evaluation, to infer whether heuristic processing happens. The *objective* position of the stimulus designed for a particular empirical investigation can be estimated as the consensus of a preliminary test for the stimulus.

In essence, information distortion that the current research seeks to measure is intentional distortion, where there is no significant deviation between individual's perception of the message attitude and the objective message attitude. It is distortion in narrow sense, and stems from individuals' goals of effort-saving or cognitive consistency(Russo et al. 2008, Shah & Oppenheimer 2008). The attitude an individual perceives from a focal stimulus and the consequential state of cognitive dissonance play critical roles in measuring information distortion in this vein. By contrast, cognitive biases in the current research are designed to measure heuristic distortion and unavoidable distortion, where the attitude perception of an individual with regard to a message remarkably departs from the true attitude attached in the message. The measure highlights the objective attitude communicated in an persuasive stimulus as a major reference point. This answers the logic behind Equation 3.2 and 3.3.

Note that, as outlined in Table 3.3, intentional distortion also leads to biased judgements. At the same time, when individual adopts the prior attitude as a heuristic in perceiving the message, information distortion also happens. So the relationships are just complicated. Technically distinguish-

ing information distortion from cognitive biases is virtually hard and unnecessary. Thus in the empirical analysis in Chapter 4, the two reciprocal cognitive responses are integrated into one framework.

Building upon the above rethinking and the nature of cognitive dissonance, the measurements of information distortion and cognitive biases in this research are designed as per the following consideration.

3.4.2 Information Distortion Measure

When strong cognitive dissonance happens (i.e., $|disson_t| \geq 2$), the information distortion, D_t, that individual i makes in response to the message can be defined as follows:

$$D_t = \begin{cases} \delta \cdot A_t - \delta \cdot A_{t-1} & \delta \cdot A_t > \delta \cdot A_{t-1} + s/8 & boomerang \\ s/8 & \delta \cdot A_{t-1} < \delta \cdot A_t \leq \delta \cdot A_{t-1} + s/8 & distortion \\ \frac{s}{8} \cdot \frac{\delta \cdot A_t - \left(\delta \cdot \bar{A}_t + s/8\right)}{\delta \cdot A_{t-1} - \left(\delta \cdot \bar{A}_t + s/8\right)} & \delta \cdot \bar{A}_t + s/8 < \delta \cdot A_t \leq \delta \cdot A_{t-1} & distortion \\ 0 & \delta \cdot \bar{A}_t - s/8 < \delta \cdot A_t \leq \delta \cdot \bar{A}_t + s/8 & assimilation \\ \delta \cdot A_t - \left(\delta \cdot \bar{A}_t - s/8\right) & \delta \cdot A_t \leq \delta \cdot \bar{A}_t - s/8 & reinforcement \end{cases} \tag{3.9}$$

where boomerang, distortion (in narrow sense), assimilation and reinforcement are the four different processing of distortion in broad sense. A greater D_t indicates the individual strongly distorts the processing of the received message. Particularly, a boomerang effect characterises that an individual makes extensive counterarguing to the incoming message, resulting in attitude change reverse to the direction advocated by the source(Hamilton et al. 1993). An assimilation effect hypothesises that an individual incorporates the elements of the new information, such as attitude, belief, knowledge, idea, value, etc., into existing cognitions, and change existing cognitive schemata(Sherif & Hovland 1962). It is a typical perspective of constructivism. Reinforcement is a reverse distorting behaviour, where an individual totally moves to the persuading direction and produces an even stronger posterior attitude than the message attitude.

The logic behind the above definition is illustrated as Figure 3.2:

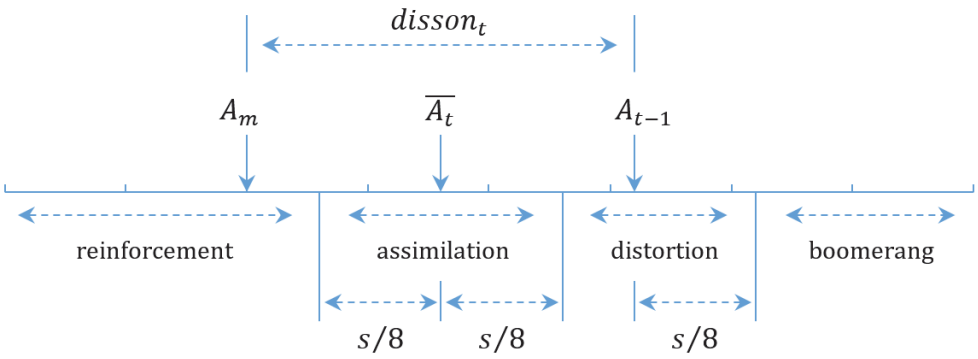


Figure 3.2: The Developed Attitude and the Corresponding Distortion Status ($|disson_t| \geq 2$)

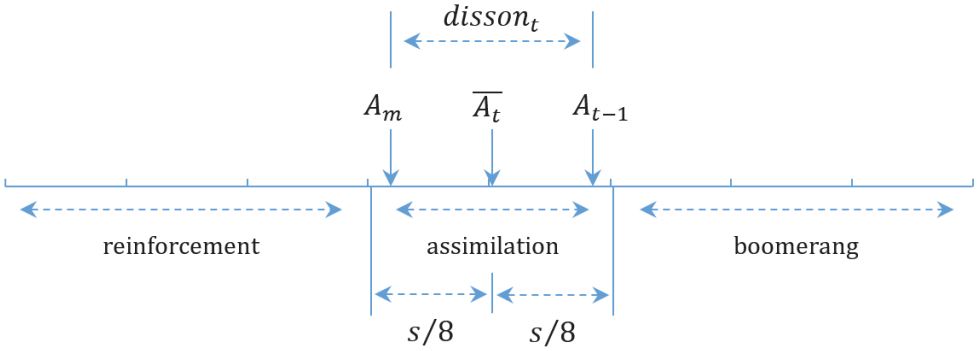


Figure 3.3: The Developed Attitude and the Corresponding Distortion Status ($|disson_t| < 2$)

When an individual is experiencing weak or trivial cognitive dissonance (i.e., $|disson_t| < 2$), the amount of information distortion, D_t, the individual makes can be measured as follows:

$$D_t = \begin{cases} \delta \cdot A_t - (\delta \cdot \bar{A}_t + s/8) & \delta \cdot A_t > \delta \cdot \bar{A}_t + s/8 & boomerang \\ 0 & \delta \cdot \bar{A}_t - s/8 < \delta \cdot A_t \leq \delta \cdot \bar{A}_t + s/8 & assimilation \\ \delta \cdot A_t - (\delta \cdot \bar{A}_t - s/8) & \delta \cdot A_t \leq \delta \cdot \bar{A}_t - s/8 & reinforcement \end{cases} \tag{3.10}$$

The logic behind the above treatment is illustrated as Figure 3.3:

Although when some magnitudes of cognitive dissonance, $|disson_t|$, are just close (form left or right) to the two deciding points (i.e., 2), the above

measurement paths may result in slight jumps in the corresponding amounts of information distortion, but for most cases, they are logically safe and acceptable.

3.4.3 Cognitive Bias Measure

The amount of cognitive bias measures the systematic deviations that distinguish the cognitions people arrive from the optimal or rational ones. As discussed above, in the context of information processing, the objective stance of a stimulus can serve as an agent for the optimal or rational evaluation regarding the stimulus. At the same time, considering that it is plausible that people make judgements by compromising between the objective attitude of a stimulus and their prior attitude, the optimal or rational evaluation can be relaxed to be this neutralised position, i.e., the unbiased attitude ($\bar{A}_t$, defined by Equation 3.3). Thus, cognitive bias in the current research is measured as follows:

$$B_t = \frac{\left|A_t - \bar{A}_t\right|}{s} \cdot 8 \tag{3.11}$$

A more simple approach to measuring cognitive bias is just consider whether the valence of attitude reached by an individual is consistent to the objective valence of the message, as follows:

$$B_t = \begin{cases} 0 & valance\left(A_t\right) = valance\left(\check{A}_m\right) \\ 1 & else \end{cases} \tag{3.12}$$

In the empirical study in Chapter 4, the simple approach is adopted.

3.5 Summary

Drawing upon the literature reviewed in Section 2.1 and 2.2 and a rethinking of some major concepts associated with information cognitive processing, this chapter step by step elaborates the measures for attitude (in different

dimensions), perception deviation, cognitive dissonance, information distortion and cognitive bias. These measures construct an important scaffolding for further empirical study and social computing in the following chapters.

As commented in Chapter 2, there has long been a notable lack of research attempts quantitatively capturing the complicated and dynamic internal mechanisms of individual information processing and the consequential distortion and biases. In this sense, as a major contribution of the present research, the measures devised in this chapter add to the literature and fill the gap of quantitative analysis. This contribution also responds to the research issue **H2** raised in Section 1.2.1.

Chapter 4

Distortion and Biases in Individual Information Processing: An Empirical Study

By conceptualisation and measurement development with regard to the attitude-relevant constructs, Chapter 3 demonstrates the mathematical transformation relationships within individual information processing. It partly pictures the variables linking to the attitude produced by an individual during processing a stimulus advocating a specific position, and portrays the accompanying distortion and biases. Grounded in the measurements, this chapter further penetrates into the precursors leading to distortion and biases, by incorporating more constructs concerning message arguments, source and the magnitude of individual elaboration and sense making.

Following the typical path of empirical study, the chapter proceeds as follows: first the conceptual framework and the underpinning hypotheses for understanding the intra-psychological mechanisms of distortion and biases in individual information processing and attitude shaping are developed and laid out; then the empirical methodology including stimuli design, instru-

mentation, data sampling and empirical manipulations is described; data are analysed in terms of descriptive statistics, reliability and validity of instruments, and fit of structural model; and finally findings are discussed. Figure 4.1 shows the organisation of this chapter.

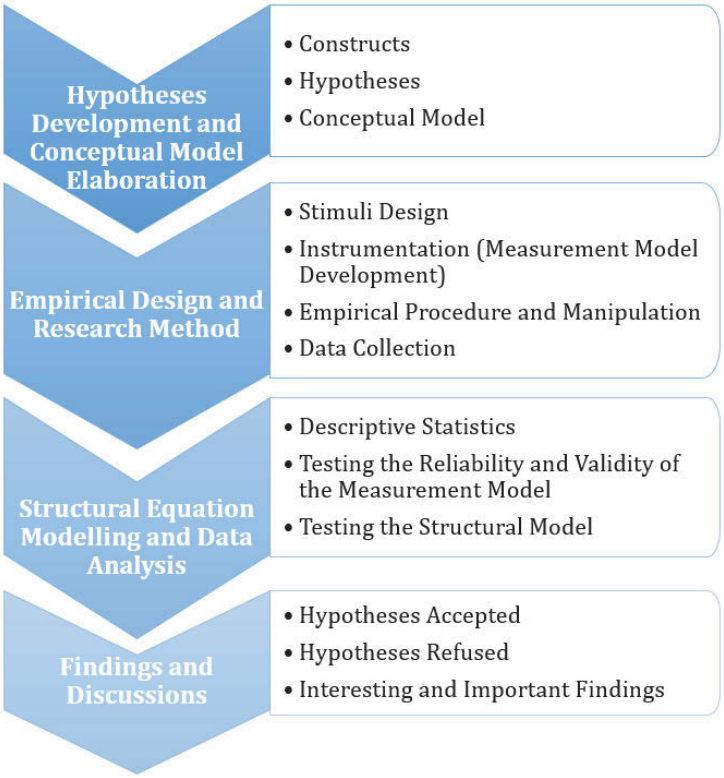


Figure 4.1: Organisation of Chapter 4

4.1 Research Model and Hypotheses

As discussed previously (Section 1.1, Section 2.1 and Section 2.2), as a complex process, individual cognitive elaboration (distorted or undistorted, biased or unbiased) and the consequential attitudinal stance are determined by a variety of characteristic factors. Factors portraying the source include expertise, attractiveness, credibility, familiarity, etc. Factors characterising the message encompass the quality, quantity and strength of the arguments

conveyed, salience/accessibility, complexity, spatio-temporal status of presentation, the hedonic and utilitarian nature, etc. Factors describing the audience cover motivation, priors, capability, personality, feeling, meta-cognition, etc. Factors depicting the judgement task/context involve distraction, time pressure, etc.

To include all these functional factors in a single treatment is technically unrealistic and essentially unnecessary. A more sensible way is to delve into the most crucial aspects. In this vein, this chapter attempts to draw a partial but critical picture of how some of these factors play their role in individuals' cognitive elaboration and attitude shift, as well as the accompanying information distortion and cognitive biases upon exposure to a stimulus attaching with specific advocacy. To this end, the chapter elaborates a structural equation model including the quality of message arguments, the adequacy of arguments, source credibility and individual prior attitude as exogenous latent constructs (causal variables), and incorporating elaboration/sense-making, perceived message attitude, individual posterior attitude, and actually distortion and biases, as endogenous latent constructs (effect variables). Particularly, the study accentuates the impacts of cognitive inconsistency between the prior attitude of an individual and the attitude advocated by the message (i.e., cognitive dissonance) on the endogenous constructs of attitude, distortion and biases.

Figure 4.2 presents the conceptual model. The causal links in the model basically conform McGuire (1968)'s information processing theory, which assumes the major steps of an individual to shape an attitude upon exposure to a persuasive stimulus, i.e., from attending, comprehending, assessing and comparing to opinion shift.

Since Chapter 3 has presented the conceptualisation and measures of the constructs of attitudes, perceived message attitude deviation, cognitive dissonance, information distortion and cognitive biases, in the following subsections, substantial attentions will be paid to other constructs labelled in Figure 4.2, including quality and adequacy of message arguments, source

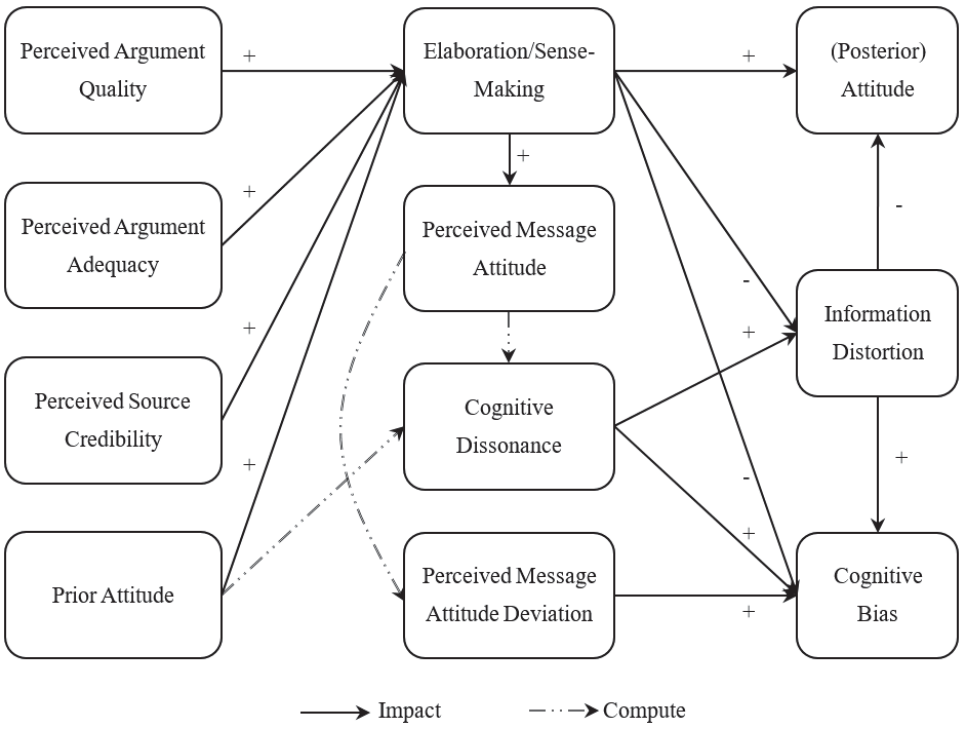


Figure 4.2: Conceptual Model for Understanding Distortion and Biases in Individual Information Processing

credibility and elaboration/sense-making.

4.1.1 Interactions among Attitudes, Distortion and Biases

Building upon the knowledge from Chapter 3, the causal interactions among attitudes, distortion and biases are hypothesised as follows:

H1: Cognitive dissonance has a positive effect on information distortion (i.e., the stronger an individual suffers a state of cognitive dissonance, the more distortion the individual makes in information evaluation and attitude formation);

H2: Cognitive dissonance has a positive effect on cognitive biases (i.e., the more an individual is confronted with a state of cognitive dissonance,

the more cognitive biases are brought about);

H3: Perceived message attitude deviation positively co-moves with the magnitude of cognitive bias;

H4: Information distortion negatively impacts (i.e., retrains) an individual's attitude shaping towards the direction of the message advocacy;

H5: Information distortion leads positively to cognitive biases (i.e., stronger information distortion signifies stronger cognitive biases).

4.1.2 Elaboration and Sense Making

Elaboration has long been the focus of literature concerning information cognitive processing, attitude formation and persuasion. Individuals' cognitive activities toward an input message are essentially projects/maps on a continuum of processing effort(Bohner & Dickel 2011). The elaboration likelihood model (ELM) postulates central processing and peripheral processing in terms of an individual's efforts invested in elaboration(Petty & Cacioppo 1986). In a like way, the heuristic-systematic processing model (HSM) assumes heuristic processing and systematic processing as per how much cognitive capacity and efforts involved in an individual's information evaluation(Chaiken 1980, Chaiken & Eagly 1989).

Although classic dual-processing models such as the above-mentioned ELM and HSM suggest different routes of information processing, the current research here just merges the different processing into one construct (named as the title of this subsection). This can be justified by Carpenter (2015)'s rethinking that since each kind of cues (central or peripheral) can give rise to different routes of processing, it is not technically necessary to distinguish these routes in empirical validations.

The theories developed by Hovland et al. (1953) and McGuire (1968) provide the earliest cues concerning the role of elaboration in attitude formation. This role is also the central concern of the above-mentioned ELM and HSM models. The general conception is, the deeper an individual elaborates on

the presented information, the more possibly that the individual will be persuaded. At the same time, it is intuitively plausible that, the more efforts an individual invests in elaboration, the more precise the individual perceives the advocacy implied in the information.

Moreover, the current research tentatively assumes that elaboration and sense-making paralleling with information distortion, serve as two competing but interacting forces for an individual to construct an attitude. One the one side, according to traditional parlance(Chaiken & Eagly 1989, Hovland et al. 1953, Kruglanski & Thompson 1999, Petty & Cacioppo 1986), elaboration is the process for an individual to reach a judgement. This process leads the individual to a message-relevant advocacy. On the other hand, to pursue cognitive consistency or effort conserving, an individual distorts the received information, swaying from the persuading course and leading to a biased judgement. Deep elaboration mitigates the effects of distorted and biased processing, whereas distorted or biased processing hampers an accurate judgement. This interactions are the major concern of the current empirical study.

To conclude, the present research hypothesises that:

H6: Elaboration/sense-making positively contributes to an individual's perception of the attitude advocated by an incoming message;

H7: Elaboration/sense-making positively impacts (i.e., fosters or drives) an individual's attitude shaping towards the direction of the message advocacy;

H8: Elaboration/sense-making negatively links to information distortion (i.e., Elaboration/sense-making mitigates the effects of information distortion); and in like way,

H9: Elaboration/sense-making negatively links to cognitive biases.

At the same time, it is intuitive, and is also implied in pertinent literature, that an individual with a favourable prior towards an advocacy will be more

willing to elaborate a advocacy-positive message. This intuition leads to the following hypothesis:

H10: Prior attitude plays an positive role in elaboration/sense-making.

4.1.3 Perceived Argument Quality

Argument quality, also referred to as argument strength, paralleling with source credibility, constitutes virtually the most critical functional antecedent of information processing in literature. As the most important statement in the elaboration likelihood model, when an individual is capable and willing to cognitively elaborate on a advocacy-relevant message, the quality of the arguments communicated within the message will determine the magnitude of elaboration(Petty & Cacioppo 1986). According to the heuristic-systematic processing model, the quality of arguments critical to a judgement task is the prerequisite for systematic processing(Chaiken 1980). Similar assertion can be inferred from Gawronski & Bodenhausen (2006)'s associative-propositional evaluation model. As reviewed by Clark (2014, p.596), "*in the majority of studies on information processing, the extent of message scrutiny has been indexed by manipulating the central merits or quality of the arguments provided in a persuasive appeal*".

Hence, it is safe to hypothesise that:

H11: Argument quality positively effects elaboration/sense-making.

4.1.4 Perceived Argument Adequacy

Although direct hints concerning argument adequacy can be rarely found from literature, argument adequacy itself can acts either as cues (or heuristics) for peripheral elaboration (or heuristic processing), or as a special body of argument quality for central (or systematic) processing, according to Chaiken & Eagly (1989) and Petty & Cacioppo (1986). Especially when persuasive message are presented on computer screens or in printed forms

(as the settings of the current empirical study), an individual can make a fast and superficial judgement on the argument adequacy by quickly scanning the communicated material. This simple count-based judgement then works as an heuristic with compelling availability. It easily comes up to the individual's mind, leading to an intuitive processing, according to Kahneman (2003).

On this found, the following hypothesis is tentatively advanced:

H12: Argument adequacy positively effects elaboration/sense-making.

4.1.5 Perceived Source Credibility

A high-credibility source demonstrating trustworthiness, validity and accuracy inspires recipients' belief in its representations(Tormala & Petty 2004, Tormala, Briñol & Petty 2006). Prior research substantiates the relevance of source credibility to information processing and attitude construction. According to Hovland et al. (1953), one of the recognised pioneers in information processing, credible communicators should be more persuasive than low-credibility ones. Heesacker, Petty & Cacioppo (1983) found that for a personally relevant counter-attitudinal issue, a highly credible source increases an individual's message-relevant thinking. DeBono & Harnish (1988) confirmed the effect of source expertise on cognitive responses including arguments recalls and postmessage attitudes. The role of source credibility in information processing is also acknowledged in contemporary theories of persuasion such as the likelihood elaboration model (Petty & Cacioppo 1986), the heuristic-systematic processing model(Chaiken 1980) and the uni-model (Kruglanski & Thompson 1999). For example, the elaboration likelihood model assumes that an individual with low involvement responses to a persuasive message primarily by reliance on peripheral cues such as source credibility, and therefore, a message from a high-credibility source is more likely to induce an attitude shift toward the message stance than a message from a low-credibility source(Petty & Cacioppo 1986). In a similar manner, the

heuristic-systematic processing model posits that an individual may reach a judgement or decision in the light of the expertise, trustworthiness, consensus, familiarity and popularity of an incoming stimulus(Chaiken & Eagly 1989). Although in many cases(Chaiken 1980, Clark, Wegener, Sawicki, Petty & Briñol 2013, DeBono & Harnish 1988, Petty & Cacioppo 1986, Tormala et al. 2006), the effects of source credibility on elaboration interact with other functional antecedents (e.g., arguments) or moderators (e.g., motivation and capability), it does not exclude the function of source credibility in varying elaboration.

The above evidence substantially justifies the following hypothesis:

H13: Source credibility positively effects elaboration/sense-making.

Table 4.1 recaps the constructs and the associated hypotheses (column 1-2) in the proposed conceptual model, and also lists the corresponding observed variables (column 3-4, as will be discussed in Section 4.2.2).

The conceptual model assumes perceived message attitude and therefore the cognitive dissonance as the effects of elaboration and sense-making. This does not necessarily exclude the reverse linkage between cognitive dissonance and elaboration, i.e., cognitive dissonance restraining elaboration, declared by the HSM model of Chaiken (1980) and the CET model of Kruglanski et al. (2012). In other words, the state of cognitive dissonance as a consequent of elaboration/sense-making and message attitude perception may restrain further elaboration. This reciprocal effects in nature do not contradict the presented conceptual model and the behind hypotheses.

4.2 Research Methods

The empirical study in this chapter was administrated by following the procedure from stimuli design, instructments design, pilot experiments, intructments improvement, formal experiments, samples collection, data analysis to model validation.

Table 4.1: Conceptual Model and Measurement Model

Conceptual Model		**Measurement Model**	
Latent Construct	**Hypothesis**	**Measured Variable**	**Question Item**
(Posterior) Attitude	**H1:** Cognitive dissonance has a positive effect on information distortion; **H2:** Cognitive dissonance has a positive effect on cognitive biases; **H3:** Perceived message attitude deviation positively co-moves with cognitive biases; **H4:** Information distortion negatively impacts an individual's attitude shift towards the message advocacy; **H5:** Information distortion leads positively to cognitive biases.	Measured as per Equation 3.1 from participants' self-briefed attitude and confidence.	
Prior Attitude			
Perceived Message Attitude			
Objective Message Attitude		Rated by invited judges.	
Perceived Message Attitude Deviation		Measured as per Equation 3.5	
Cognitive Dissonance		Measured as per Equation 3.6	
Information Distortion		Measured as per Equation 3.9 or 3.10	
Cognitive Biases		Measured as per Equation 3.12	
Elaboration/ Sense Making)	**H6:** Elaboration/sense-making positively contributes to an individual's perception of the message attitude; **H7:** Elaboration/sense-making positively impacts an individual's attitude shift towards the message advocacy; **H8:** Elaboration/sense-making negatively links to information distortion; **H9:** Elaboration/sense-making negatively links to cognitive biases; **H10:** Prior attitude plays an positive role in elaboration/sense-making.	Cues Recall	Reported by participants, coded by invited judges, and refined by reliability analysis.
		Informativeness	**Q1:** The above material is informative for my evaluation on the proposal of holding the PX plant;
		Helpfulness	**Q2:** The above material is helpful for my evaluation on the proposal of holding the PX plant;
		Perplexity Resolving	**Q3:** The above material does remove my perplexity in evaluating the proposal of holding the PX plant;
		Efficiency Improving	**Q4:** The above material does improve my efficiency in evaluating the proposal of holding the PX plant.

Table 4.2: Conceptual Model and Measurement Model (Cont.)

Conceptual Model		**Measurement Model**	
Latent Construct	**Hypothesis**	**Measured Variable**	**Question Item**
Perceived Argument Quality	**H11:** Argument quality positively effects elaboration/sense-making.	Relevance	**Q5:**The arguments presented in above material are of relevance;
		Accuracy	**Q6:** The arguments presented in above material are accurate;
		Logic Soundness	**Q7:** The arguments presented in above material are logically sound;
		Objectivity	**Q8:** The arguments presented in above material are objective.
Perceived Argument Adequacy	**H12:** Argument adequacy positively effects elaboration/sense-making.	Plurality	**Q9:** The above material contains a plurality of arguments;
		Diversity	**Q10:** The above material contains a diversity of arguments.
Perceived Source Credibility	**H13:** Source credibility positively effects elaboration/sense-making.	Trustworthiness	**Q11:** The sources of the information presented in the above material are trustworthy;
		Expertise	**Q12:** The sources of the information presented in the above material demonstrate expertise or authority;
		Integrity	**Q13:** The sources of the information presented in the above material demonstrate the quality of integrity;
		Reliability	**Q14:** The sources of the information presented in the above material are reliable.

4.2.1 Stimuli Design

To accurately investigate into individuals' attitude development during their information processing (distorted or undistorted, biased or unbiased), the stimuli to which the experiment participants will be exposed should be carefully tailored. First, the stimuli should be sufficiently relevant to the participants, to ensure they are effectively motivated (or involved) to elaborate and make sense from the stimuli (Eveland 2001, Jensen 2011, Petty, Cacioppo & Schumann 1983, van Strien et al. 2016). Information for recreation or gossips may not be able to engage participants in information processing. Secondly, the topic of the stimuli should be somewhat controversial. Those topics or messages driving uni-valance, i.e., arousing aversion (or inciting pleasure) of the substantial majority, are not suitable for systematic observations of the effects of attitude-relevant precursors. What's more, the stimuli should be persuasive. In other words, the stimuli should be able to provide supportive evidence for the participants to change their attitude toward the stance advocated by the stimuli. In addition, in order to test the effects of cognitive dissonance, the attitude implied by the stimuli should be guaranteed consistent with the prior attitudes of part of the participants, and at the same time inconsistent with the existing attitudes of the others.

Besides the above considerations, the author and his research team were also aware that a barrage of negative events ignited by chemical industries and environmental issues and catalysed by Internet media recent years have resulted in remarkable distorted public opinions, many even with no scientific basis. For example, recent years, projects of p-Xylene (an aromatic hydrocarbon, hereafter abbreviated as PX) plants have attracted substantial public concerns. Voices of favour and disfavour have been contesting for a long time. On one side, in cities such as Shanghai, Xiamen, Dalian, Ningbo, Maoming etc., a series of mass civic protests matched around chemical plants and governmental buildings. On the other side, about ten students from Tsinghua University, majoring in chemistry, defended the entry of PX on Baidu Baike, an online encyclopaedia similar to Wikipedia, from being changed to "highly

toxic" by people who stood in the stream of protests. [1] Moreover, we found from preliminary investigations that there was also controversy in PX toxicity among university participants, some of whom changed their attitudes after reading our materials advocating low-toxicity.

Building upon the above accounts, we chose the PX-relevant topic as the theme for stimuli design. Particularly, we suppose that there is a policy proposal to hold rather than abolish or relocate a PX plant, which is 10 kilometres away from the regions listed in national regulations, is granted all required production licenses, and meets the national security prerequisite rules of production, storage, operation, management, business use and transportation for hazardous chemical industries (hereafter referred to as PX-holding proposal). Our stimuli were then designed and manipulated to favour the PX-holding proposal, which involves the following 6 pieces:

- National regulations on the safe management of hazardous chemicals specifying that, no plant whose productions involve highly toxic or hazardous chemicals can be planed or built less than 1000 meters to the regions such as the residential regions, protected areas of water sources and water supplies, major ways of transportations (including driveways, highways, railways, subways and waterways), natural reserves, regions for livestock husbandry, resorts, and regions of military facilities (with positive valance with respect to the above PX-holding proposal);

[1] Media coverage can be found at:

- http://www.reuters.com/article/china-protests-idUSL3N0ZD07K20150627.
- https://www.theguardian.com/environment/2011/aug/14/china-protest-against-px-chemical-plant.
- https://www.washingtonpost.com/world/asia_pacific/ningbo-protest-response-both-typical-of-chinas-environmental-debate/2012/10/29/ac4c8e5e-21f6-11e2-8448-81b1ce7d6978_story.html.
- http://www.bbc.com/news/world-asia-pacific-14520438.
- http://www.bbc.com/news/world-asia-china-26849814.
- http://www.globaltimes.cn/content/853037.shtml.

- Benefits of PX for national economy and environments (positive);
- Students from Tsinghua University defending the entry of PX on Baidu Baike (positive);
- Public protests against PX plants (negative);
- The safe and profitable running of PX plants in the U.S., Singapore, and Japan (positive);
- The China central and provincial governments' cautiousness on PX-relevant projects (neutral).

The cues of the sources of each pieces of information were also implied to enable participant's source perception, e.g., media coverage or national regulations.

Fifteen trained judges, blind to our research hypotheses, were invited to a preliminary test to objectively evaluate the attitude attached in the above designed stimuli. A consensus was reached that the stimuli held a favouring position for PX-holding proposal. A Likert 7-point scale (where 1-7 indicates a level from strong disfavour to strong favour for attitude, very unconfident to very confident for confidence) was used to collect their scores and their confidences. Their scores were then adjusted as per Equation 3.1, resulting in a final average attitude (the objective material attitude) of 5.64 ($SD = 0.94$), i.e., a fair favour. Inter-judge reliability was estimated using Krippendorff's α(Hayes & Krippendorff 2007) and was proved high ($\alpha = 0.92$).

A second material was designed in the same spirit to the above one for testing the effects of sequential exposure. Its average adjusted attitude calculated on judge rates is also fairly favourable ($M = 5.45, SD = 1.12, \alpha = 0.91$).

Hereafter, the first material is referred to as Material-I, whereas the second as Material-II.

4.2.2 Instrumentation

The instruments for constructs in the conceptual model are devised by referring to existing empirical studies, and are validated and refined on the

basis of preliminary investigations. All instruments were pretested prior to use on the formal sample of participants. Part of the results of preliminary investigations can be found from Wan (2015) and Cen, Wang, Wan & Tao (2016).

The rationales behind the instruments design are as follows:

Attitudes, Distortion and Biases

Chapter 3 presents detailed designs for the measures associated with attitudes, perceived message attitude deviation, cognitive dissonance, information distortion and cognitive biases[2].

Prior attitude,perceived message attitude and posterior attitude are measured as per Equation 3.1 from participants' self-briefed attitude and confidence. The questions for eliciting participants' prior attitude take the form as follows:

Q: Personally, your current attitude towards the policy proposal of holding the PX plant is...

Q: Your confidence in the above attitude is...

Participants were asked to rate their responses to the above questions on 7-point Likert scales. For attitude, 1 stands for strongly disfavour, 2 fairly disfavour, 3 a bit disfavour, 4 neither disfavour nor favour, 5 a bit favour, 6 fairly favour, and 7 for strongly favour. For confidence, 1 represents very unconfident, 2 fairly unconfident, 3 a bit unconfident, 4 neither unconfident nor confident, 5 a bit confident, 6 fairly confident, and 7 for very confident.

[2]Note that the measures of perceived message attitude deviation and cognitive dissonance conceptualised in section 3.2 and 3.3 have a reverse signal connection with the constructs hypothesised in the conceptual framework in Section 4.1, so when testing the structural model, we use the negative values of the measures. However, when showing the statistics in Section 4.3 and discussing the effects of these two constructs in Section 4.4, we use their raw measured values.

Questions for participants' perception of message attitude take similar form and are responded as per the same scales as above. The instructions are as follows:

Q: Concerning the policy proposal of holding the PX plant, the attitude advocated by the above material (note, not yours) is...

Q: The confidence expressed by the above material in its advocated attitude is...

In a like manner, the questions for collecting participants' posterior attitude are designed as follows:

Q: After reading and thinking about the above material your attitude towards the policy proposal of holding the PX plant is...

Q: Your confidence in the above attitude is...

The objective message attitude is measured based on rates from invited judges, as described in the above section.

Elaboration and Sense Making

Thought-listing technique invented by Cacioppo & Petty (1981) was extensively adopted to plumb the magnitude of elaboration, e.g., by Carpenter & Boster (2013*a*), Carpenter & Boster (2013*b*), DeBono & Harnish (1988), Holmstrom, Bodie, Burleson, McCullough, Rack, Hanasono & Rosier (2015) and Jensen (2011). Participants in their experimental settings were prompted to write down what they were thinking about while processing the presented materials on 12 blank text-boxes. Trained judges, blind to all research hypotheses, were invited to code participants' briefs. Inter-judge reliability was checked through, e.g., inter-class correlation or Krippendorf's alpha (Hayes & Krippendorff 2007), based on which disagreements were resolved. The number of issue-relevant thoughts then served as an agent for elaboration. Besides, Jensen (2011) also measured *recognition* (for testing participants' message recall) and *comprehension* (for testing participants' capacity in applying the information from the presented materials to new situations) by using

structure-consistent multiple-choice questions tailored for the presented stimuli. Participants' responses to each question were coded as correct or incorrect, and were summed up to a single scale as indicators for recognition and comprehension. Besides measuring arguments recalls using thought-listing technique, Carpenter & Boster (2013*a*) and Carpenter & Boster (2013*b*) also calculated the level of cognitive elaboration from participants' self-rated questionnaires, consisting of 12 items on a 7-point response scale borrowed from Reynolds (1997), e.g., how much a participant thinks was attempting to analyse the issues in the message. Equipped with an eye-tracking system, van Strien et al. (2016) gauged participants' fixation time on different parts (e.g., text, logos and about-us information) of the presented websites from the recorded eye movements of the participants. They used the estimates of fixation time as measures for participants' processing and evaluating the information from the websites. Moreover, in van Strien et al. (2016)'s experimental settings, the participants were also asked to write topic-relevant essays without looking back to the websites they have gone through. The researchers coded the number of arguments included into participants' essays as another indicator for participants' sense-making. The first approach employed by van Strien et al. (2016) is unrealistic for the current research. Nonetheless, thought-listing technique is borrowed.

In the current empirical study, the participants were also asked to recall the elements (either arguments or cues) presented in the materials. Each participant's recall rate was coded by several invited team members (as judges) and was then checked for reliability (Krippendorff's $\alpha = 0.92$ for the first material, and $\alpha = 0.93$ for the subsequent material, signifying highly reliable). This message recall was then included as one important account for elaboration.

Moreover, the utility an individual perceived from elaboration of information is also considered as a manifestation of elaboration. In other words, how much sense an individual makes from elaboration reflects the amount of elaboration. It is in this regard that sense-making and elaboration parallel in

naming the corresponding construct in Figure 4.2. Theoretical and empirical basis can be found from previous work. Particularly Holmstrom et al. (2015) introduced perceived message helpfulness as the effect indicator of message assessment, and measured it as per four 5-point semantic differential scales, i.e., helpfulness, appropriateness, sensitiveness, and effectiveness. In the pioneering study concerning the influential model of technology acceptance, Davis (1989) synthesised insights from different research streams and conceptualised perceived usefulness as performance enhancing. Davis (1989) devised an instrument for perceived usefulness from several runs of validations and refinements, resulting in a 6-items measure, including work quickening, performance improving, productivity increasing, effectiveness, work easing, and usefulness. The declared excellent psychometric characteristics of the instrument seeded a remarkable bulk of subsequent research. By revising Davis (1989)'s measure, Sussman & Siegal (2003) instrumented usefulness in the scenario of informational influence in organisations as per value, informativeness and helpfulness, each with one item on a Likert 7-point scale.

The current empirical study hires part of the above measurements, especially those from Davis (1989)'s scales, and at the same time underscores the context of information processing. The facets for interpreting perceived utility in this study are informativeness (or the quality of being referential), helpfulness, perplexity resolving, and efficiency improving. Each facet is observed as per one instrument item on a Likert 7-point scale ranging from 1 (strongly disagree) to 7 (strongly agree), as follows:

Q1: The above material is informative for my evaluation on the policy proposal of holding the PX plant;

Q2: The above material is helpful for my evaluation on the policy proposal of holding the PX plant;

Q3: The above material does remove my perplexity in evaluating the policy proposal of holding the PX plant;

Q4: The above material does improve my efficiency in evaluating the policy

proposal of holding the PX plant.

Perceived Argument Quality

Petty, Cacioppo & Morris (1983) assessed message quality (referred to as message evaluation in their study) through a 5-item × 9-point instrument, covering communication effectiveness, delightfulness, convincingness, the quality of well-written and the quality of intriguing judgements or reasoning. In a series of empirical studies administrated by Carpenter and Boster, argument quality was induced for within-group analysis by composing valid argument structures and strong evidence to meet strong arguments premises, and including logical errors with weak evidence to support weak arguments premises(Carpenter & Boster 2013*a*, Carpenter & Boster 2013*b*). In addition, they also assessed participants' perceived argument strength by borrowing seven 7-point semantic differential items (compelling/not compelling, convincing/unconvincing, logical/illogical, reasonable/unreasonable, sound/unsound, believable/not believable, and plausible/not plausible) from La France & Boster (2001). Sussman & Siegal (2003) counted argument quality as per completeness, consistency and accuracy, each with one item on a Likert 7-point scale.

On the basis of above meta-analysis, the construct of arguments quality in the current empirical study is decomposed into four constituents, i.e., relevance, accuracy, logic soundness and objectivity, whose meanings are literally obvious. Single instrument item on a Likert 7-point scale ranging from 1 (strongly disagree) to 7 (strongly agree) is tailored for each constituent, as follows:

Q5: The arguments presented in above material are of relevance;

Q6: The arguments presented in above material are accurate;

Q7: The arguments presented in above material are logically sound;

Q8: The arguments presented in above material are objective.

Perceived Argument Adequacy

Two aspects of argument adequacy are measured, i.e., plurality and diversity, each with one item on a Likert 7-point scale ranging from 1 (strongly disagree) to 7 (strongly agree) as follows:

Q9: The above material contains a plurality of arguments;

Q10: The above material contains a diversity of arguments.

Perceived Source Credibility

Although in some investigations, e.g., of DeBono & Harnish (1988),Clark et al. (2013) and Knobloch-Westerwick et al. (2015), source credibility was induced for within-group analysis, references of instrumentation of credibility can still be found. van Strien et al. (2016) asked participants to rate the trustworthiness, expertise, and convincingness of the information of each different websites on 6-point scales. Metzger, Hartsell & Flanagin (2016) expounded perceived source credibility in terms of bias, professionalism and trustworthiness, and assessed credibility using 4 items on Likert 5-point scales. Sussman & Siegal (2003) instrumented source credibility as per competence and trustworthiness, each with 2 items on Likert 7-point scales. Actually, the definition advanced by Tormala et al. (2006), and Chaiken & Eagly (1989) as well, afford the accounts of source credibility, e.g., trustworthiness, validity, accuracy, expertise, consensus, familiarity, popularity, etc.

Drawing upon all these instrumentations and considering the controversy of the presented materials, the current research explicitly observes source credibility as per four semantic differential dimensions, including trustworthiness, expertise (or authority), integrity and reliability, each with one question item on a Likert 7-point scale from 1 (strongly disagree) to 7 (strongly agree). To avoid the perplexity in the components of argument quality and source credibility, validity (actually referred to as logic soundness) and accuracy were carefully included into the measures of message quality, as discussed above. The question items were designed as follows:

Q11: The sources of the information presented in the above material are trustworthy;

Q12: The sources of the information presented in the above material demonstrate expertise or authority;

Q13: The sources of the information presented in the above material demonstrate the quality of integrity;

Q14: The sources of the information presented in the above material are reliable.

4.2.3 Procedure

Volunteer participants, typically university students, were invited through emails. Under their acceptance and consent, they were administrated to the experiment place. They were seated in front of our computers, where an web-based experimental system was pre-installed. They were asked to follow the instructions on the web pages and complete all the required questions. There were typically 7 web pages (i.e., 7 steps) for participants to go through, as depicted in Figure 4.3. During each step, they could not move back to previous ones.

During cues recalls, they were free to write down their thoughts concerning the elements (either arguments or cues) presented in the materials. Once completing all the steps, participants were thanked and rewarded.

The time participants spent to complete each step was recorded by the system, which was then used for further validating their cognitive efforts.

To ensure a decent motivation level of participants, like the manner in the investigations of Carpenter & Boster (2013*a*) and Carpenter & Boster (2013*b*), participants were told prior to the experiment that, although they could respond anonymously to the questions, their responses will be compiled into an investigation report, which will be submitted to a specific governmental department for policy decisions. Motivation manipulation was test by debriefing the participants about their thought of personal relevance and

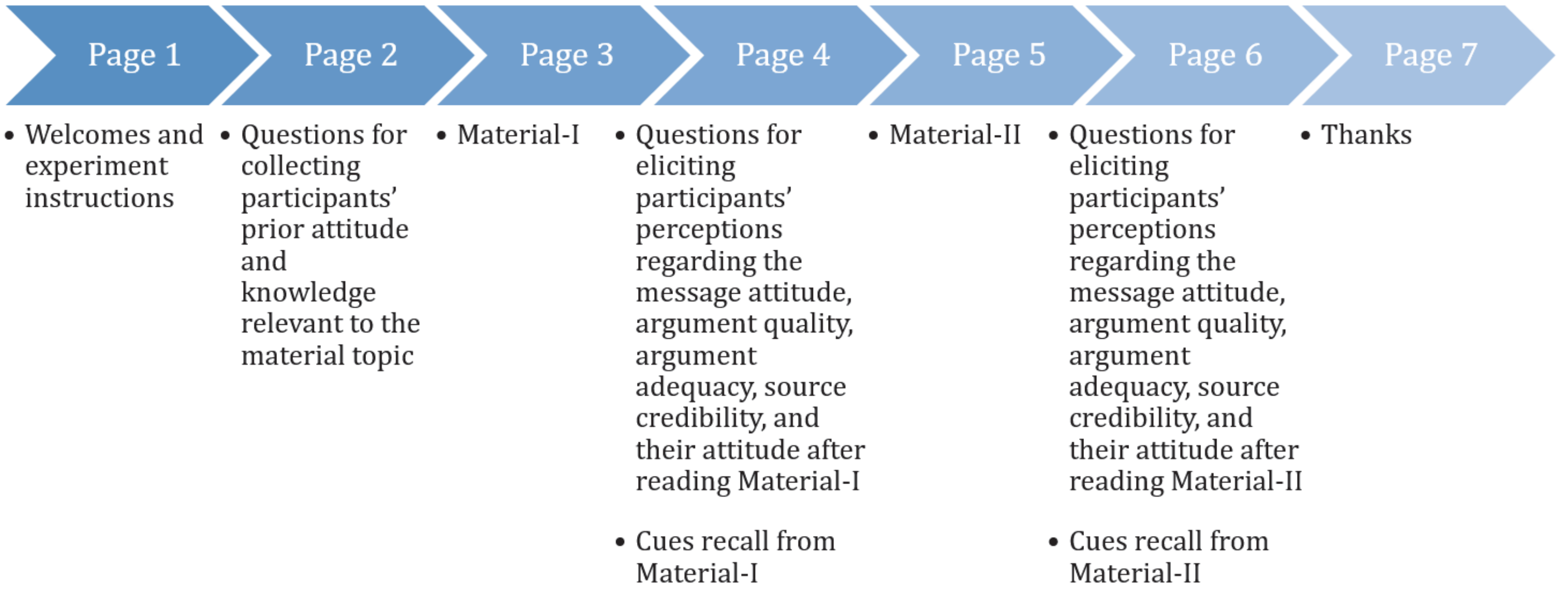


Figure 4.3: Procedure of Empirical Study

their attention paid to scrutinise the presented materials in the last step. The debrief took the following way and participants were required to respond on 7-point scales from strongly disagree to strongly disagree:

Q: Generally, I think the topic associated with the presented materials are of relevance to me;

Q: Personally, I think I have paid much attention to the presented materials.

Post-experiment analysis shows that, the average time participants took ($M = 13.6\ minutes, SD = 4.2$) is close to the time the trained pre-testers took($M = 14.1\ minutes, SD = 2.8$) in a pilot experiment. At the same time, participants' reports to the above two questions hold the means of 6.1, and 5.9, with standard deviations of 0.68 and 1.32. Take all these indicators into account, it is safe to say that participants' motivation was effectively manipulated.

4.2.4 Data Collection

Totally, 480 invitation emails were sent, and 303 participants were recruited into the experiments, in which 281 samples were regarded valid. Rates of invitation acceptance and valid samples were 62.9% and 92.7%.

4.3 Data Analysis

Data analysis proceeded in three stages: (1) descriptive statistical analysis for a profile of the scale items; (2) measurement modelling for psychometric evaluation of the instruments; and (3) structural modelling for hypotheses testing. SPSS 17.0 software and AMOS 22.0 software were employed for data analysis.

4.3.1 Descriptive Statistics

Descriptive statistics corresponding to the measured variables listed in 4.1, on the basis of Material-I, were inspected using SPSS. Table 4.3 sketches the profile of statistics.

The statistics of prior attitude demonstrate a slight aversion to the stimulus materials from the majority of the participants. The construct of prior attitude holds the lowest mean value (3.391) among all the constructs. Nonetheless, there is still manifest controversy over the material advocacy, as can be inferred from the remarkable standard deviation of the prior attitude unadjusted by confidence (1.740, the highest standard deviation among all the variables scaled on [1,7]). This corroborates the effectiveness of the stimuli design. The mean distance between participants' prior attitudes and the decent positive attitude of the material itself (the objective message attitude is 5.640, rated by the invited judges, whereas the mean of participants' perception of the message attitude is 5.392; both are favourable) ensures the significance of cognitive dissonance(the mean of dissonance is -2.169, bigger than the significant level defined in Section 3.1.3). This benefits the exploration of the effects of cognitive dissonance.

There is trivial deviation (with a mean of -0.248) of participants' perception of the message attitude from the objective message attitude. In other words, It was not that difficult for the participants to catch the advocated points of the material. According to the discussions in Section 3.4.1, when there is no significant perception deviation, the distortion made by an individual can be attributed to intentional distortion to achieve cognitive consistency.

All the means associated with participants' elaboration and sense-making, and their perceptions of arguments and sources, are higher than the middle point of the scales. That is to say, generally, the material designed was constructive for participants' attitude shaping and therefore is effective in testing the effects of information distortion and cognitive biases. If participants' attitude shifts do not match their perceptions and elaboration, dis-

Table 4.3: Descriptive Statistics

Latent Construct	**Measured Variable**	**Question Item**	**Range**	**Mean**	**Standard Deviation**
Elaboration/ Sense Making	Cues Recall	-	$[0, 1]$	0.597	0.192
	Informativeness	Q1	$[1, 7]$	5.140	1.531
	Helpfulness	Q2	$[1, 7]$	5.188	1.530
	Perplexity Resolving	Q3	$[1, 7]$	4.738	1.426
	Efficiency Improving	Q4	$[1, 7]$	4.839	1.612
Perceived Argument Quality	Relevance	Q5	$[1, 7]$	5.086	1.600
	Accuracy	Q6	$[1, 7]$	4.989	1.441
	Logic Soundness	Q7	$[1, 7]$	5.849	1.171
	Objectivity	Q8	$[1, 7]$	4.769	1.527
Perceived Argument Adequacy	Plurality	Q9	$[1, 7]$	4.280	1.797
	Diversity	Q10	$[1, 7]$	4.500	1.723
Perceived Source Credibility	Trustworthiness	Q11	$[1, 7]$	4.538	1.510
	Expertise	Q12	$[1, 7]$	4.623	1.522
	Integrity	Q13	$[1, 7]$	4.742	1.436
	Reliability	Q14	$[1, 7]$	4.683	1.412
Prior Attitude			$[1, 7]$	3.391	1.480
—Prior Attitude Unadjusted by Confidence			$[1, 7]$	3.242	1.743
—Prior Confidence			$[1, 7]$	5.032	1.647
Perceived Message Attitude			$[1, 7]$	5.392	1.274
—Perceived Message Attitude Unadjusted by Confidence			$[1, 7]$	5.691	1.243
—Perceived Message Confidence in Attitude			$[1, 7]$	5.975	1.342
Objective Message Attitude (Rated by Judges)			$[1, 7]$	5.640	0.940
Perceived Message Attitude Deviation			$[-8, 8]$	-0.248	1.274
Cognitive Dissonance			$[-8, 8]$	-2.669	2.312
Posterior Attitude			$[1, 7]$	4.447	1.297
—Posterior Attitude Unadjusted by Confidence			$[1, 7]$	4.495	1.533
—Posterior Confidence			$[1, 7]$	5.253	1.250
Information Distortion			$[-8, 8]$	0.011	0.583
Cognitive Biases			$(0, 1)$	0.446	0.498

torted or biased information processing happens. However, from the statistics of posterior attitude ($M = 4.447, SD = 1.300$), information distortion ($M = 0.060, SD = 0.897$) and cognitive biases($M = 0.446, SD = 0.498$), it is hard to judge whether and how much distorted or biased processing contributed to (or more precisely, prevented or restrained) participants' attitude construction. Further inspections are therefore justified.

4.3.2 Reliability and Validity of Instruments

The objective of measurement modelling is to assess the reliability and validity of the instruments developed in Section 4.2.2. Typically, the reliability and validity can be judged in terms of internal consistency, convergent validity and determinant validity. All these three kinds of testing can be achieved with Confirmatory Factor Analysis using AMOS.

Cronbach's α and composite reliability (CR) are measures of internal consistency, which indicating the degree to which a set of instrument items pertained to a specific latent construct correlates with and predicts the construct. A multi-item instrument for a latent construct with a Cronbach's α larger than 0.7 and a CR exceeding 0.8 is regarded as internally consistent and reliable(Fornell & Larcker 1981, Kline 1998). Table 4.4 provides the testing results of Cronbach's α and CR for each construct included into the present empirical study, all exceeding the corresponding thresholds and therefore demonstrating adequate measurement reliability and stability.

Convergent validity decides whether similar constructs correspond with each other, whereas discriminant validity tests whether dissimilar constructs can be easily differentiated. Confirmatory factor loadings and average variance extracted (AVE) are effective indices for convergent validity. According to Bagozzi & Yi (1988) and Hairs, Anderson, Tatham & Black (1998), for a instrument system with excellent psychometric validity, the loading of each measured factor should be larger than 0.5, and at the same time, the AVE of each construct should exceed 0.5. As exhibited in Table 4.4, all outcomes of factor loading and AVE meet the standards, assuring the convergent validity

of the measurement model of this empirical study. Discriminant validity can be justified when the square root of the AVE for each construct is higher than the bivariate correlation coefficients between that construct and all the others, as recommended by Fornell & Larcker (1981). Table 4.5 displays the matrix of correlation coefficients for all the constructs in this empirical study. Diagonal values are the square roots of AVE for the constructs, below which are the bivariate correlation coefficients, with each lower than the corresponding diagonal value. This tells that all constructs in the current empirical study carry ample discriminant validity.

In a scheme of things, the instruments developed in Section 4.2.2 are substantiated reliable and valid.

4.3.3 Structural Model Testing

The fit of the proposed research model was evaluated in terms of several common criteria for structural equation model testing(Hairs et al. 1998). Table 4.6 presents the fit indices. Although the value of indicator GFI (0.88) is slightly lower than the acceptable level (0.90), the other indices indicate that the theoretical model overall adequately fit the empirical data.

Table 4.7 summarises the results of structural equation analysis, including the coefficients and significance levels of the hypothesised paths.

As shown in Table 4.7, 8 hypothesised pairs of positive effect and 3 pairs of negative effect are accepted, whereas 2 hypothesised pairs of effects are refused. Figure 4.4 illustrates the final structural model.

4.4 Discussion

Most of the hypotheses developed from literature are tested for acceptance under a holistic research framework. Particularly, the roles of argument quality, source credibility in individuals' information processing and attitude (i.e., **H6**, **H7**, **H11** and **H13**) shaping are reconfirmed with definite significance levels, which are mediated by the degree of their elaboration/sense-making.

Table 4.4: Reliability and Convergent Validity

Latent Construct	**Measured Variable**	**Standardised Factor Loading**	**AVE**	**CR**	**Cronbach's α**
Elaboration/ Sense Making	Cues Recall	0.865	0.637	0.816	0.789
	Informativeness	0.821			
	Helpfulness	0.701			
	Perplexity Resolving	0.694			
	Efficiency Improving	0.597			
Perceived Argument Quality	Relevance	0.795	0.554	0.865	0.741
	Accuracy	0.781			
	Logic Soundness	0.576			
	Objectivity	0.668			
Perceived Argument Adequacy	Plurality	0.574	0.520	0.802	0.726
	Diversity	0.596			
Perceived Source Credibility	Trustworthiness	0.650	0.704	0.827	0.758
	Expertise	0.687			
	Integrity	0.717			
	Reliability	0.695			

Cognitive dissonance works as a critical nexus, leading to distorted and biased processing and negative attitude construction (**H1** and **H2**). Participants' prior attitudes did not change their way of scrutinising the presented materials in the current empirical settings (as **H10** is refused). Although prior to the experiment, participants exhibited slight disfavour to the advocacy manipulated in the presented materials, they finally make a shift towards the advocacy after reading Material-I. The difference between participants' overall prior attitude and their post-material attitude is $4.447 - 3.391 = 1.056$.

Table 4.5: Discriminant Validity

Construct		A	B	C	D	E	F	G	H	I	J	K
Elaboration/Sense Making	**A**	**0.798**										
Perceived Argument Quality	**B**	0.358	**0.744**									
Perceived Argument Adequacy	**C**	0.074	0.161	**0.721**								
Perceived Source Credibility	**D**	0.732	0.326	0.218	**0.839**							
Prior Attitude	**E**	0.085	0.068	0.112	0.217	**1.000**						
Perceived Message Attitude	**F**	0.421	0.298	0.211	0.313	0.419	**1.000**					
Perceived Message Attitude Deviation	**G**	-0.068	0.031	0.057	0.102	0.065	-0.106	**1.000**				
Cognitive Dissonance	**H**	-0.148	-0.137	0.036	0.172	0.266	0.521	0.132	**1.000**			
Posterior Attitude	**I**	0.587	0.595	0.217	0.503	0.412	0.213	-0.112	-0.421	**1.000**		
Information Distortion	**J**	-0.279	-0.164	-0.065	-0.009	-0.521	0.125	0.216	0.190	-0.540	**1.000**	
Cognitive Biases	**K**	-0.301	-0.092	0.073	-0.103	-0.095	0.114	0.225	0.257	-0.170	0.215	**1.000**

Table 4.6: Indices of Model Fit

Fit Index	χ^2/df	RMSEA	GFI	AGFI	IFI	CFI	NFI
Value in this study	3.28	0.076	0.88	0.89	0.934	0.92	0.97
Acceptable level*	< 5	< 0.08	> 0.9	> 0.8	> 0.9	> 0.9	> 0.9

* : see Hairs et al. (1998) for more discussions about the acceptable levels.

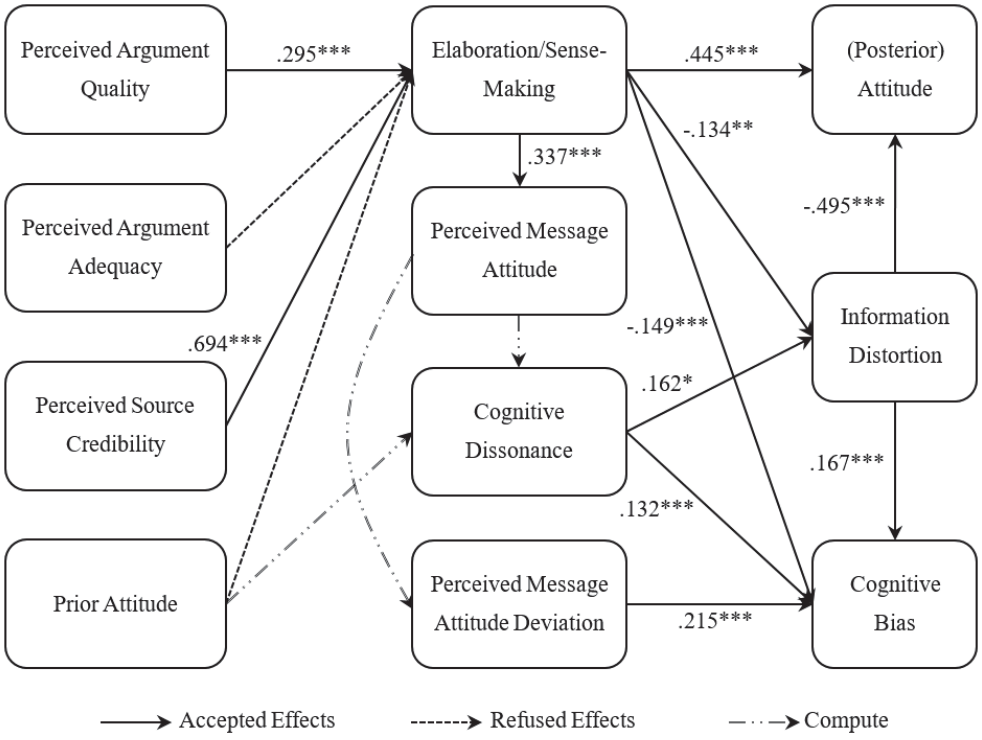


Figure 4.4: Path Analysis Results of the Structural Equation Model

After mapping this difference onto the scale illustrated by Figure 3.1, it is actually $1.056 \cdot 8/6 = 1.408$, suggesting a slight significant shift. The reason that participants' prior attitudes did not prevent their moving towards the advocacy of the stimuli could be attributed to the empirical manipulations, including the controversy of the advocacy and participants' motivation. In other words, when being confronted with a unfavourable topic but of sub-

Table 4.7: Results of Structural Model Testing

Path	**Hypothesis**	**Coefficient**	t**-value**	**Significance Level**
Cognitive Dissonance → Information Distortion	H1	0.162	**2.012***	**Significant**
Cognitive Dissonance → Cognitive Biases	H2	0.132	**7.374*****	**Significant**
Perceived Message Attitude Deviation → Cognitive Biases	H3	0.215	**7.798*****	**Significant**
Information Distortion → (Posterior) Attitude	H4	-0.495	**-5.714*****	**Significant**
Information Distortion → Cognitive Biases	H5	0.167	**4.521*****	**Significant**
Elaboration/Sense-Making → Perceived Message Attitude	H6	0.337	**3.657*****	**Significant**
Elaboration/Sense-Making → (Posterior) Attitude	H7	0.445	**5.173*****	**Significant**
Elaboration/Sense-Making → Information Distortion	H8	-0.134	**-3.193****	**Significant**
Elaboration/Sense-Making → Cognitive Biases	H9	-0.149	**-4.890*****	**Significant**
Prior Attitude → Elaboration/Sense-Making	H10	0.078	1.677	Not Significant
Perceived Argument Quality → Elaboration/Sense-Making	H11	0.295	**3.715*****	**Significant**
Perceived Argument Adequacy → Elaboration/Sense-Making	H12	0.063	1.342	Not Significant
Perceived Source Credibility → Elaboration/Sense-Making	H13	0.694	**6.717*****	**Significant**

* : significant with $|t| > 1.96$, and $P < 0.050$;

** : significant with $|t| > 2.58$, and $P < 0.010$;

*** : significant with $|t| > 3.29$, and $P < 0.001$;

$^{\text{no } *}$: statistically insignificant.

stantial relevance, it is still possible for individuals to make a change. No substantial effect of argument adequacy can be discerned in the current empirical context (as **H12** is refused). The reason may be that it was difficult for the participants to make precise evaluation on the plurality and diversity of the stimuli arguments, and the reported scores ($M = 4.280, SD = 1.797$ for plurality measure, and $M = 4.500, SD = 1.723$ for diversity measure) are discrete and uncorrelated with the construct of elaboration/sense-making.

Besides the above points, some special and important accounts are discussed as follows.

4.4.1 Interactions between Elaboration for Sense-Making and Distortion for Consistency

Figure 4.4 depicts the interactions among the constructs of elaboration/sense-making, cognitive dissonance, distortion and biases, and the constructed outcome of attitude. It confirms the hypotheses (i.e., **H4-H9**) regarding the competing but interacting forces in individual information processing as pictured in Section 4.1.2. Whether an individual is deep engaged in elaborating an input stimulus functions whether the individual makes a shift to the position advocated the stimulus. When personal relevance is installed, the goal of elaboration is to secure a meaningful and even accurate judgement, therefore it contributes to an attitude towards the stimulus advocacy (**H7**), by carefully inquiring into and making sense from the position and novel information conveyed by the stimulus (**H6**). Follow a constructivism course, the novel cognition will be updated into the individual's schemata. However, this does not always work. When an individual's existing cognitions dominates over the incoming ones, the state of possible dissonance will drive the individual to distort the information and to persist existing cognitions, ending up in a biased judgement and attitudinal preference(**H4** and **H5**). The current research also reveals the effect of elaboration and sense-making in defending against distorted or biased processing (**H8** and **H9**). An individual has to balance or compromise between these two paralleling and competing forces.

The findings in this vein are similar to Kruglanski et al. (2012)'s cognitive energetic theory and the motivation perspectives of Chaiken & Eagly (1989), Eagly & Chaiken (1993) and Lundgren & Prislin (1998), and at the same time provide more empirical details.

4.4.2 Effects of Cognitive Dissonance

As discussed in Section 3.3, cognitive dissonance plays an critical role in distorted and biased information processing. This role is also empirically unravelled by the current empirical study, as suggested by the accepted hypotheses **H1** and **H2**. Figure 4.5 illustrates the linkage between cognitive dissonance and information distortion (panel (a)), cognitive biases (panel (b)) and individuals' attitude shaping (panel (c)). It seems from the middle part of panel (a) that when there occurs no distortion, the points of dissonance show no statistical trend (the downward line is the artefact of points arraying, not the real trend). As defined in Section 3.4.2, if no distortion happens, an individual assimilates the new elements from an message exposure, and makes a balance or compromise between prior cognitions and the new ones. It could take place in different dissonance conditions. However, the two sides of panel (a) make a difference. On the left side, where the amounts of distortion are negative, individuals actually make positive moves towards the message-relevant advocacy, resulting in their posterior attitude even exceeding their perception of the message advocacy. This is actually a process of reinforcement learning as defined in Section 3.4.2. By contrast, on the right side, where the amounts of distortion are positive, individuals are making distorted processing or even counterarguing with a boomerang effect. This is the distortion in real sense. By comparing the distributions of cognitive dissonance on the two sides, it is safe to say that stronger dissonance leads to stronger distortion. Similar conclusion regarding the nexus between cognitive dissonance and cognitive biases can be drawn from panel (b). Although the effect of cognitive dissonance on post-message attitude is not explicitly hypothesised in the conceptual model, from panel (c), their

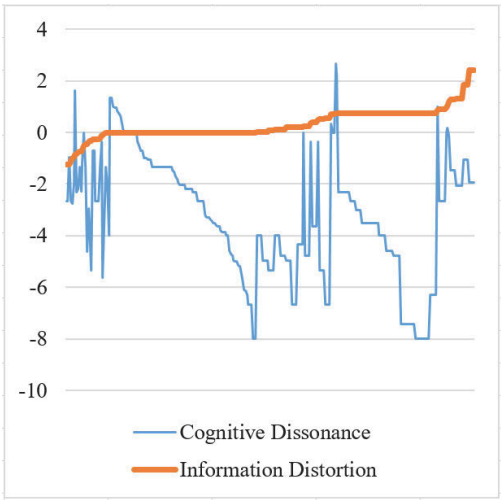
correlation can still be found. There is slight up-trend displaying that the less individuals feel a state of dissonance, the more positively they stand in alignment with the message-advocacy. However, it is just slight. As discussed in above section, individuals' elaboration and sense-making intervenes this effect. This provides further evidence for the complicated interactions among elaboration/sense-making, cognitive dissonance, distortion and biases, and posterior attitude.

Although in the conceptual framework, only the effect of perceived message attitude deviation on cognitive biases is assumed, hints of its possible causal links to information distortion and posterior attitude can still be inferred from Figure 4.6. Although its effect on posterior attitude is even slighter, compared to that of cognitive dissonance.

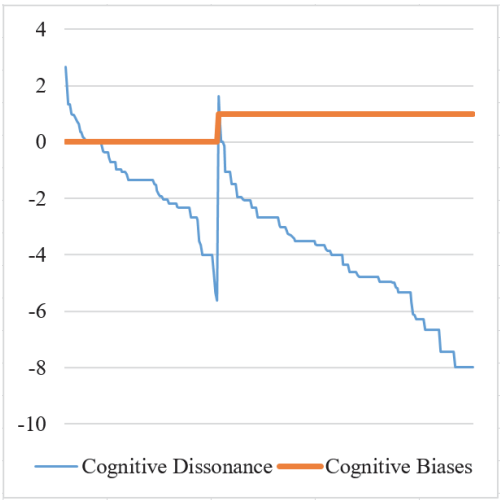
4.4.3 Effects of Sequential Exposure

As reviewed in Section 2.1.5, the majority of prior research regarded individuals' information elaboration as an independent process, and technically ignored the effects of sequential exposure. Partly in response to Bohner & Dickel (2011)'s appeal, this empirical study preliminarily explores the changes in major attitude-relevant measures within individuals' exposure to sequential advocacy-compatible messages. As described in Section 4.2.1 and 4.2.3, two stimuli materials with a same stance (i.e., fairly favour the PX-holding proposal) were designed and the participants were debriefed about their cognitions during each material exposure. The mental measures corresponding to each exposure are contrasted in Table 4.8.

An shown in Table 4.8, after scrutinising the first material, participants shaped an attitude of slight favour ($M = 4.495, SD = 1.533$ for the attitude unadjusted) with fair confidence ($M = 5.253, SD = 1.533$). Then after processing the second material with similar positive stance towards the PX-holding issue, both the attitude and confidence of the participants were enhanced ($M = 4.855, SD = 1.512$ for the attitude unadjusted, and $M = 5.409, SD = 1.258$ for confidence). Although the significant level of im-



(a)



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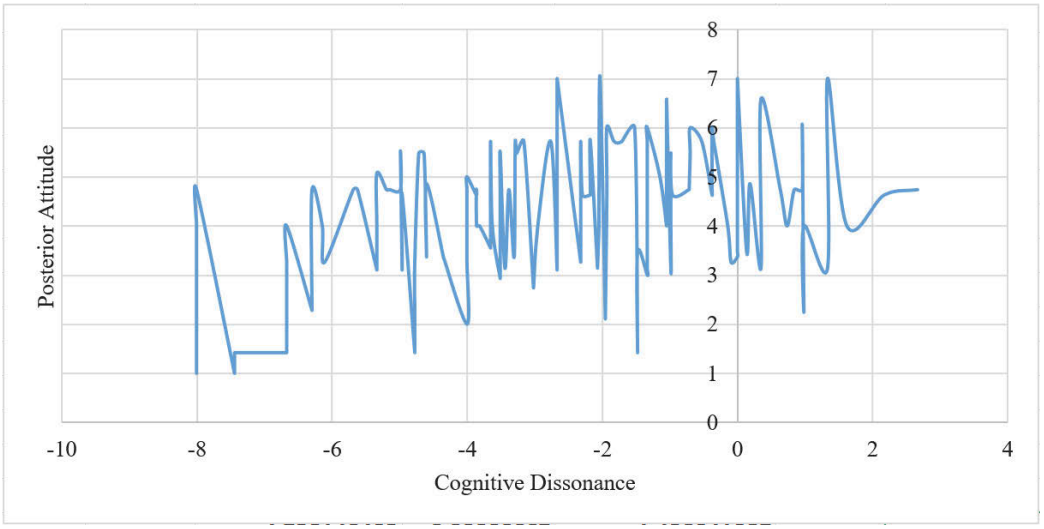
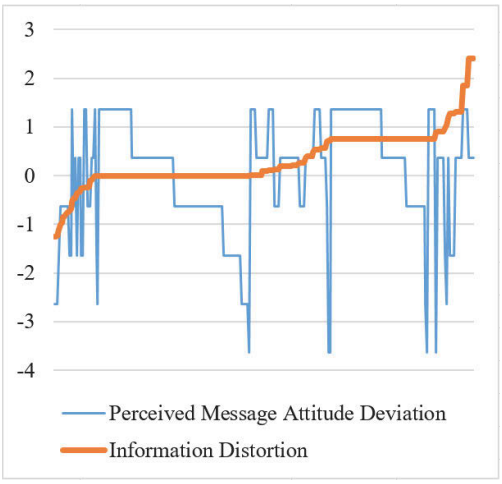


(c)

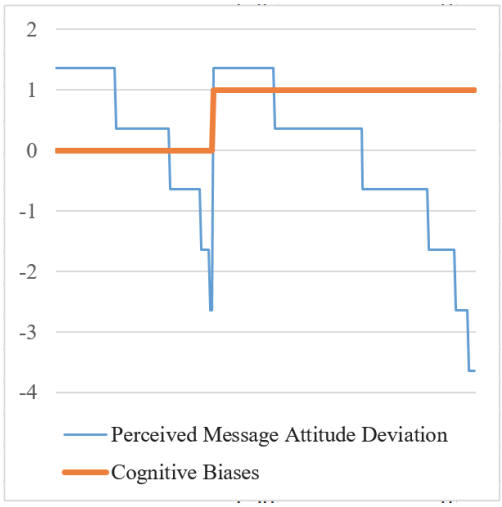
Figure 4.5: The Effects of Cognitive Dissonance on Attitude Shaping, Distortion and Biases

provement ($(4.736 - 4.447) \cdot 8/6 = 0.385 < 2$) is not remarkable, but for one re-exposure, it still justifies the existing of the effects of sequential exposure. What's more, cognitive dissonance decreased by $|1.024 - 2.669| = 1.645$.

Figure 4.7 illustrates the changes in distortion and biases by arraying



(a)



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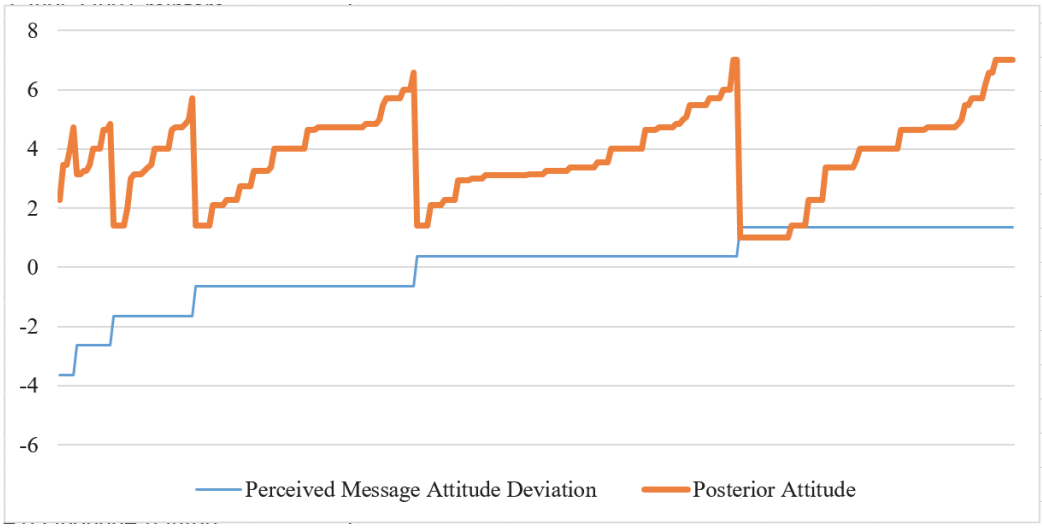


(c)

Figure 4.6: The Effects of Perceived Message Attitude Deviation on Attitude Shaping, Distortion and Biases

participant points from high-low as per the two exposures. It can be easily found that both distortion and biases reduce after sequential exposure.

Note that in the current empirical context, subject to the limitations in efforts and costs, experiments testing sequential exposure to multi-valance

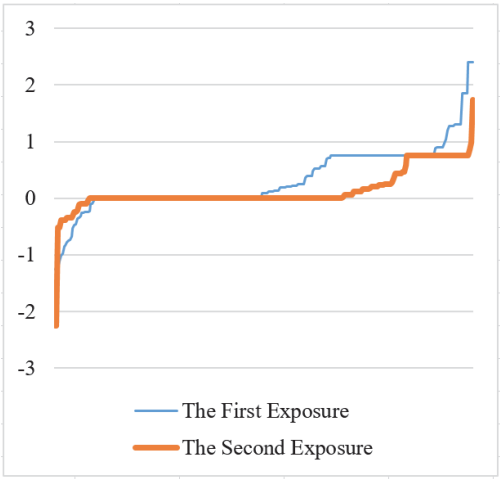
Table 4.8: Measure Changes after Sequential Exposure

Measures	Range	Material-I		Material-II	
		Mean	Standard Deviation	Mean	Standard Deviation
Prior Attitude	$[1, 7]$	3.391	1.480	4.447	1.297
—Prior Attitude Unadjusted by Confidence	$[1, 7]$	3.242	1.743	4.495	1.533
—Prior Confidence	$[1, 7]$	5.032	1.647	5.253	1.250
Perceived Message Attitude	$[1, 7]$	5.392	1.274	5.215	1.701
—Perceived Message Attitude Unadjusted by Confidence	$[1, 7]$	5.691	1.243	5.542	1.651
—Perceived Message Confidence in Attitude	$[1, 7]$	5.975	1.342	5.837	1.429
Objective Message Attitude (Rated by Judges)	$[1, 7]$	5.640	0.940	5.450	0.910
Perceived Message Attitude Deviation	$[-8, 8]$	-0.248	1.274	-0.235	1.701
Cognitive Dissonance	$[-8, 8]$	-2.669	2.312	-1.024	2.680
Posterior Attitude	$[1, 7]$	4.447	1.297	4.736	1.329
—Posterior Attitude Unadjusted by Confidence	$[1, 7]$	4.495	1.533	4.855	1.512
—Posterior Confidence	$[1, 7]$	5.253	1.250	5.409	1.258
Information Distortion	$[-8, 8]$	0.011	0.583	0.078	0.379
Cognitive Biases	$(0, 1)$	0.446	0.498	0.360	0.481

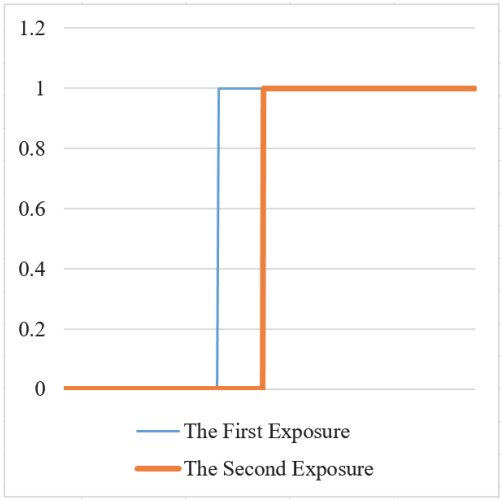
messages have not been administrated, which are planned into further research.

4.4.4 Contributions and Limitations

In response to the notable lack of empirical studies incorporating quantitative measures of information distortion and cognitive biases, this empirical study opens up the road for research in the very line. The research design and empirical procedure provide substantial references for further studies, al-



(a) Changes in Information Distortion



(b) Changes in Cognitive Biases

Figure 4.7: Changes in Distortion and Biases after Sequential Exposure

though some limitations must be acknowledged. First, no moderating effect was detected from the empirical analysis, although we have attempted to. Since the stimuli designed in this study did not cover the chemical expertise of PX, so it did not much involve the participants' own knowledge. Secondly, motivation was induced in the current study and therefore the role of motivation in moderating the proposed conceptual model could not be revealed. Knowledge and motivation has been two important inputs for research attempts in information processing and attitude development. At the current stage, the findings afford no substantial cues for these antecedents.

4.5 Summary

By elaborating a conceptual model underpinned by the causal hypotheses associated with the constructs such as argument quality, argument adequacy, source credibility, elaboration/sense-making and the attitude-relevant constructs conceptualised in Chapter 3, this chapter responds to the first research issue raised in Section 1.2.1 concerning the underlying mechanisms and influencing factors driving distortion and biases in individual information

processing. By designing the approach to empirical investigations including the stimuli manipulation, instrumentation, empirical procedure and data collection, this chapter affords an empirical solution for the research issues (**I8** and **I9**) identified in Section 1.2.3, i.e., how to test the conceptual model and how to conduct the laboratory experiments. Moreover, data analysis and findings discussion partly and tentatively resolve issue **I10** declared in Section 1.2.4 regarding the implications of the theoretical and methodological research in real-world decision-making or judgement contexts.

The empirical study in this chapter leads to some interesting findings as follows:

- Perceived message quality and perceived source credibility have positive impacts on an individual's elaborating and making sense of an incoming persuasive stimulus, which contributes to the individual's attitude shift towards the stimulus advocacy;
- The state of cognitive dissonance drives an individual to distortedly and biasedly process the inconsistent cognitive elements implied in an persuasive stimulus, which then restrains the individual from moving towards the stimulus advocacy;
- Individuals' elaboration of an incoming stimulus for sense-making and their information distortion for consistency are two paralleling and competing forces for attitude construction, which reflects the complicated nature of human information processing behaviour;
- Cognitive dissonance plays a critical role in the above two competing forces;
- Sequential exposure to advocacy-consistent stimuli may gradually alleviate individuals' information distortion and cognitive biases.

The cognitive and behavioural characteristics revealed in this chapter equip important knowledge for the social computing model at individual level in next chapter.

Chapter 5

Distortion and Biases in Individual Information Processing Under Social Impact: Social Computing

Chapter 4 seeks to solve the first issue elicited in Section 1.2, by delving into the intra-psychological laws of individual information processing and attitude shaping, and the major drivers of information distortion and cognitive biases. The study provide us with the fundamental insights of individual behaviour involved in information processing. However, as previously accented, human beings are situated in social settings, and their behaviour are inevitably influenced by social information. Both direct impact (e.g., mutual or group interactions among a population of individuals) and indirect impact (e.g., normative impact, group pressure, etc.) from social systems will end up with situations totally different to the attitude outcomes resulted from the information processing at the individual level. As argued by Nowak et al. (1990), behaviour mechanisms operating on individual levels of social reality may lead to unforeseeable emergent consequences in higher levels of the entire society, which, in turn, will change the social context facing lower level indi-

viduals. To observe the distortion and biases in a much wide social context and in a longitudinal way, this chapter will synthesise the research outcomes of previous chapters and bring into the vehicles of social computing. Particularly, in this chapter, an integrative model conceptualising the causal and procedural relationships involved in individual information processing will be elaborated, which will be bridged with a social contagion model. Then the systems-theoretical models will be translated to computer programs, and social computing experiments will be carried out by running the programs. In this way, different pictures of emergent social effects of distortion and biases will be laid out, by marshalling the settings of the social composition and structure.

5.1 Research Design

To combine the cognitive information processing mechanisms of individuals at the bottom level with the evolutionary mechanisms of complex systems at the top level in a same research design framework, two models must be delicately devised (Cen, Tao, Ma & Wang 2016, Mosler & Martens 2008, Sobkowicz 2009). The first model mirrors the intra-psychological change processes of individuals with reference to their information processing and environmental behaviour. The second model characterises the inter-individual contagion effects with in a society, namely, social network model.

At the same time, the theoretical models should be translated into social computing models. This translation involves scrutinizing the assumptions confirmed by the laboratory experiments and those well established in the mass of relevant research, identifying the variables as well as their relationships implied in the assumptions, formulating the assumptions and variables into a systems-theoretical model, and defining the transitional functions reflecting the relationships among the variables. Then, the models can be computerized through the agent-based modelling tools (such as NetLogo, Swarm, Repast and MASON, etc.) or programming from scratch (the way

the current research takes).

5.1.1 Model at Individual Level

Based on the knowledge we learned in Chapter 3 and Chapter 4, as well as the mass of literature, a general explanatory model at individual level is devised as Figure 5.1.

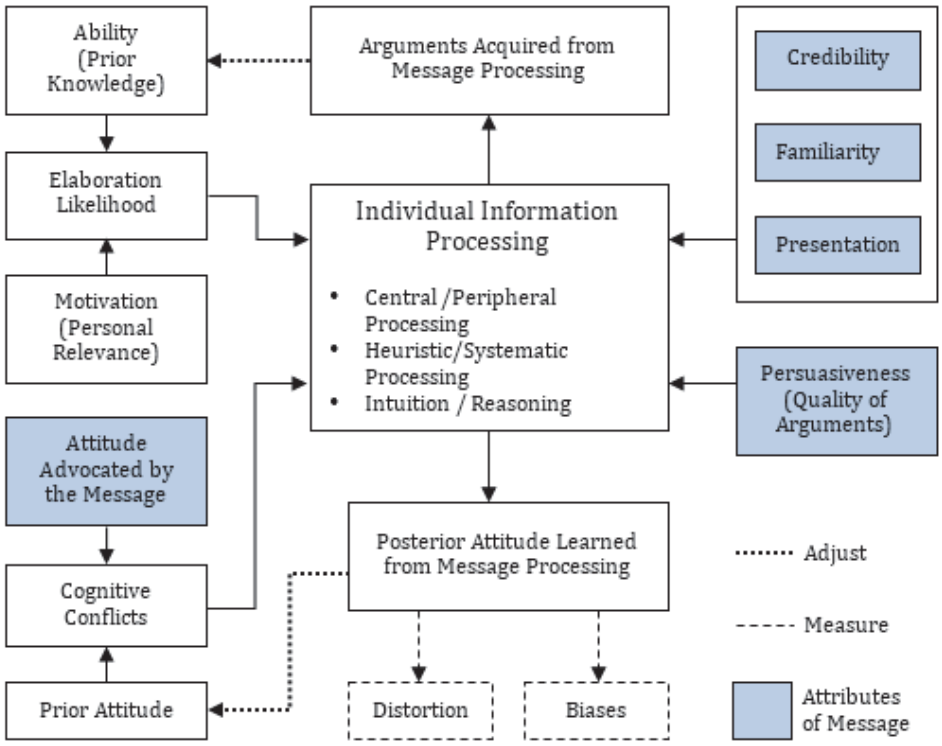


Figure 5.1: A Synthesised Model Accounting for Distortion and Biases in Individual Information Processing

However, a comprehensive investigation covering all the details contained in Figure 5.1 calls for a thorough scrutinisation of all the empirical evidence from the literature, careful confirmations of the evidence, and delicate translations of the relationships implied in the evidence into computational transformations. A more sensible way is to highlight the points that has carried out in Chapter 4, as well as the points from those established models with

sufficient computational information. Hence, the current research synthesises the insights from Chapter 3 and Chapter 4, the mathematical interpretation of the elaboration likelihood model confirmed by Mosler et al. (2001) and Hamilton et al. (1993), as well as the quantitative translation of the social judgement theory by Hunter, Danes & Cohen (2014). The elaboration likelihood model is originally developed by Petty & Cacioppo (1986), whose basic postulations has been reviewed in Chapter 2.

Particularly, the current research integrates the knowledge acquired in Chapter 4 regarding the relationships between the posterior attitude and its antecedents, including perceived arguments quality, perceived source credibility, and the most important one, cognitive dissonance. At the same time, the measures of distortion and cognitive biases developed in Chapter 3 are also incorporated.

Before moving to the computing model of individual information processing, the characteristics associated with a focal message is delineated as follows[1]:

- **Attitude**. A message is supposed to advocate a persuading attitude, which is mathematically denoted as att_m.
- **Arguments**. Arguments are the substantial content (in contrast to the peripheral cues) communicated in a message. The strength of arguments is denoted as arg.
- **Cues**. The strength of peripheral cues, represented as cue, calculates the tendency of the cues (such as the amount of arguments, the credibility, expertness or authoritativeness of the source, the familiarity or

[1]To simplify the modelling, all the variables in this chapter, if no special note is given, sample their values in a continuum of $[0, 100]$. Typically, 50 is the neutral point without tendency, values greater than 50 are supposed to favour a persuasive message, whereas values less than 50 are supposed to disfavour the message. In other words, variables are gauged with reference to the orientation of the message. For example, when we say a person take a prior position of 80, it means the position of the person is in alignment with the message.

intimacy of the audience with the message, the clarity of the message presentation or framing, and so on) to favour the persuasion purpose of the message. As evidenced by the findings of Chapter 4, these cues positively correlated the attitude change towards the persuasive direction.

In social computing, the individuals are mapped to *agents*. The computing model at individual level involves the following relationships with regard to the mental processing of an computing agent:

- **Motivation**. Individuals' motivation to cognitively process a stimulus is determined by individuals' perceived relevance of the stimulus (Petty, Cacioppo & Schumann 1983). Thus, the computational transformation of motivation, $motiv$, is simply defined as:

$$motiv = relev \tag{5.1}$$

  where $relev$ measures personal relevance.

- **Ability**. Individuals' ability to cognitively process a stimulus depends on their prior knowledge, compromised by external distractions, such as time pressure, and multi-tasks, etc. The ability, $abilit$, is therefore computed as:

$$abilit = know_{t-1} \cdot (1 - \frac{distract}{100}) \tag{5.2}$$

  where $know_{t-1}$ stands for individuals' prior knowledge, and $distract$ represents the amount of distraction, with a scale of $[0, 100]$.

- **Elaboration likelihood**. According to Petty & Cacioppo (1986), the likelihood of individuals to thoughtfully elaborate a focal message depends on whether the advocacies attached with the message highly concern them, and whether they have the cognitive capability to make

a elaboration. Providing this understanding, the elaboration likelihood, $lelaborat$, is transformed as follows:

$$lelaborat = \sqrt{motiv \cdot abilit} \tag{5.3}$$

- **Prior attitude**. The prior attitude an individual advocates is symbolised as att_{t-1} in the present scenario.

- **Cognitive dissonance**. Slightly dissimilar to definitions of Equation 3.6, in the present scenario, the cognitive dissonance, $disson$, is formalised as a *signed* difference between the advocacy of the stimulus and the prior orientation of the individual:

$$disson_t = att_m - att_{t-1} \tag{5.4}$$

- **Peripheral factor**. The peripheral factor characterises the ration of information an individual can possibly acquire from peripheral processing. Since peripheral processing happens typically in a heuristic way, it change the attitude and knowledge of the individual in a superficial way. In some sense, the peripheral factor calibrates the message impact terms of the peripheral cues (e.g., determined by the individual's perceived familiarity with or credibility of the incoming message). In mathematical definition, the factor, $fperiph$, is a mitigated measure of peripheral cues as follows:

$$fperiph = \begin{cases} (cue - 50)/50 & cue \geqslant 50 \\ 0 & else \end{cases} \tag{5.5}$$

- **Central factor**. The central factor models the ration of information an individual can potentially comprehend from central processing. This information constitutes the factors that may update the attitude or knowledge structure of the individual. According to Petty & Cacioppo (1986) and Petty & Cacioppo (1984), when engaging in thoughtful

processing, individuals identify and distinguish persuasive and shallow arguments from the stimulus. Consequently, strong arguments convert individuals' attitude towards the persuasive purpose, whereas weak arguments prevent their attitude moving to the persuasive direction. Technically, the central factor, $fcentr$, is transformed in the following logic:

$$fcentr = \begin{cases} fperiph \cdot (arg - know_{t-1})/100 & arg > know_{t-1} \\ 0 & else \end{cases} \tag{5.6}$$

The spirit behind the above computation features the reality that, when the arguments attached with the focal stimulus is a subset of individuals' knowledge, they may just ignore what they have already know; at the same time, when individuals infer no impact from the peripheral cues (i.e., $fperiph$), they may also avoid processing the stimulus.

- **Posterior attitude**. Firstly, the attitude change is proportional to the ration of sense that an individual can make from elaborating the incoming stimulus when cognitive dissonance are moderate. The sense comes from both central processing and peripheral processing, and leads to perceptions of usefulness and reliability (as examined in Chapter 4). Intuitively, peripheral cues (e.g., perceived source credibility) may mediate attitude shaping: positive cues facilitates positive attitude shaping, while negative cues prevent positive attitude shaping. This mediating role is contingent on the individual's likelihood of elaboration. When the elaboration likelihood derived from motivation and ability is moderate, the role of cues in individuals' information processing maximises. By contrast, when the elaboration likelihood is very high, individuals may pay little attention to cues; whereas when the likelihood is very low, they are also not willing to make a judgement by reliance on cues.

In this vein, the ration of sense, *sense* is therefore defined as follows:

$$sense = \frac{lelaborat}{100} \cdot fcentr + \alpha \cdot (1 - \frac{|lelaborat - 50|}{50}) \cdot fperiph \quad (5.7)$$

where α is a tempering factor with a value typically smaller than 0.5.

When there is no distorted information processing, the posterior attitude, att_{t-1}, can be directly computed as follows:

$$att_t = att_{t-1} + sense \cdot disson_t \quad (5.8)$$

However, as evidenced by Chapter 4, when there are substantial cognitive dissonance, individuals may bias their mental elaboration on the stimulus, to defend their own position. In this way, individuals may overestimate the arguments in agreement with their prior attitude and suppress the arguments communicating incongruent orientations. In other words, those consonant arguments lead to greater positive reshaping of individuals' attitude, whereas dissonant arguments incur a resistance or even a boomerang. Definitely, cognitive dissonance distorts the central processing. Similarly, when there is significant cognitive dissonance, the effect of cues also discounts. This logic is implemented by introducing a function of cognitive dissonance, $\theta(disson)$. In essence, $\theta(disson)$ models the relationship between information distortion and cognitive dissonance discussed in Chapter 4. In order to elicit the mathematical interpretation of this relationship, we simply mapping the findings in Chapter 4 regarding this relationship onto a cognitive curve as Figure 5.2:

The above curve can be easily transformed to the computing as follows:

$$\theta(disson) = \begin{cases} \delta \cdot \gamma \cdot (|disson| - |disson|^2 / 50) & |disson| \leq 50 \\ \delta \cdot \lambda \cdot (100 - 3\,|disson| + |disson|^2 / 50) & |disson| > 50 \end{cases} \quad (5.9)$$

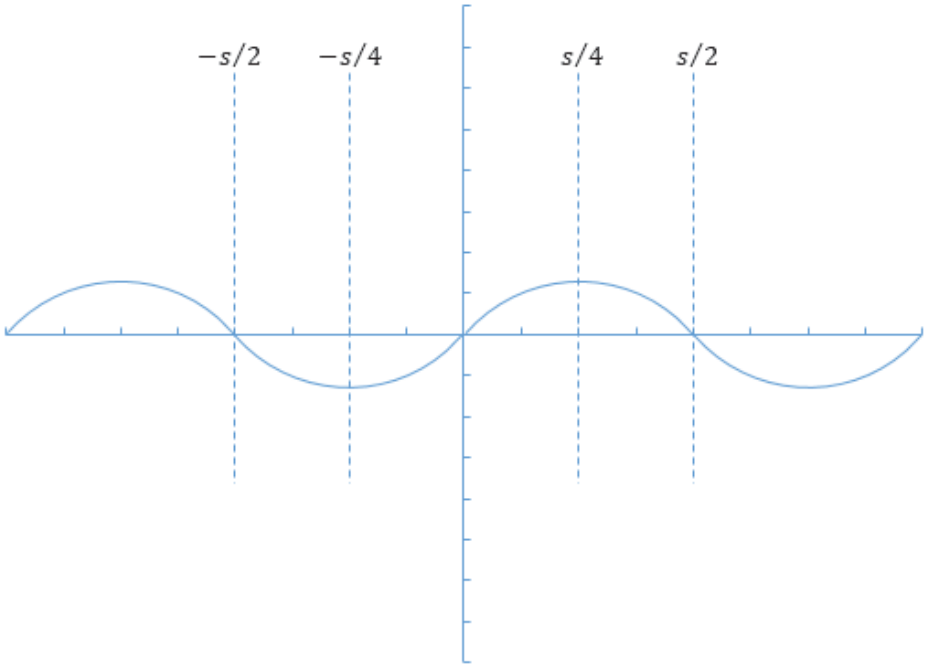


Figure 5.2: The Relationship between Information Distortion and Cognitive Dissonance

where γ is a reinforcement factor (typically greater than 1), λ is a boomerang factor (typically smaller than 1), and δ is a signal function, with 1 indicating positive dissonance, and -1 a negative dissonance, as defined in Equation 3.4

In the above spirit, the posterior attitude, att_{t-1}, is computed as follows:

$$att_t = att_{t-1} + sense \cdot \theta(disson) \tag{5.10}$$

- **Posterior Knowledge**. In a like manner to the computation of posterior attitude, the posterior knowledge that an individual build after ab-

sorbing new substantial information from the received stimulus, $know_t$, can be updated as follows:

$$know_t = \begin{cases} know_{t-1} + lelaborat \cdot fcentr & |disson| \leq 25 \\ know_{t-1} + lelaborat \cdot fcentr \cdot \frac{50-|disson|}{25} & 25 < |disson| \leq 50 \\ know_{t-1} & |disson| > 50 \end{cases} \tag{5.11}$$

Another version of posterior knowledge in the settings where no information distortion happens is as follows:

$$know_t = know_{t-1} + lelaborat \cdot fcentr \tag{5.12}$$

- **Distortion**. The amount of information distortion of each individual at each evolving iteration is computed as Equation 3.9 and 3.10. The overall distortion at the societal level gauges the average of the information distortion of all individuals.

- **Bias**. To measure the overall bias at the societal level, in a like manner, we use the absolute difference between the posterior attitude and the message attitude as the measure of bias, $bias$, as follows:

$$bias = |att_t - att_m| \tag{5.13}$$

5.1.2 Model at Societal Level

Drawing upon the literature regarding complex network models, e.g., regular network models, random network models, small-world network model (Watts & Strogatz 1998, Zanette 2002), scale-free network model (Barabási & Albert 1999) and other complex social network models (Newman 2003)(Sobkowicz 2009, for a review), the section seeks to identify the compositional and dynamic properties of social networks, therefore to analyse their potential ef-

fects on social interactions. The properties (with the ones in a bold face to be implemented in later sections) include (but are not limited to):

- **Population**: count the number of individuals in a society.
- **Mean attitude**: specifies the overall attitude of the society towards an advocacy.
- **Mean relevance**: specifies the overall level of public concern with the advocacy-relevant issue.
- **Mean knowledge**: specifies the overall knowledge of the society towards the advocacy-relevant issue.
- **Contact degree**: denotes the number of contacts an individual connects to.
- **Interconnectivity**: indicates whether the impact between any pair of individuals is unidirectional or reciprocal. the current research takes the reciprocal way.
- Distance/similarity between individuals: includes physical (i.e., temporal or spatial) distances/similarities and ideological distances/similarities (i.e., the distances/similarities between the social presences or ideologies of any two individuals).
- Strength of connection between individuals: e.g., affinity (or familiarity) versus alienation between two individuals.
- **Heterogeneity**: characterises the heterogeneity of the individuals in a society.
- Node size: indicates the social influence of an individual.
- Cluster effect: pictures the distributions of social sub-groups.

- **Dynamics**: specifies whether the social structure is static or dynamic. When a society is dynamic, during each iteration of social computing, some old contacts among the agents are disconnected, and new connections are build as per specific rules. The current research reconstructs the society by randomly connecting or disconnecting of the agents.

5.1.3 Bridging the Dual-Observation Models

One of the highlights of the current research is to integrate the model of individual information processing and the model of social contagion into a dual-observation model to bridge the gap between information processing at the individual scale and social interactions and evolution of attitude at the collective scale.

Intuitively, the interaction between individuals refers to that, the ith individual sends to the jth individual a message advocating an attitude and individual j processes the message and forms her own attitude. This way of interaction is also a process of mental interpretation of the message. In the spirit of Figure 5.1, the mappings of properties between a regular message sourced from a medium and a message interacted by two individuals are illustrated in Table 5.1.

To match the computing settings of this chapter, the persuasiveness in Table 5.1 will be treated as arg, whereas the familiarity, credibility and presentation will be integrated into *cue*, as modelled above.

Figure 5.3 presents the basic processing model of social impact between dual agents, where the inner area of the box corresponding to each agent stands for the intra-mechanisms underlying the agents information processing, as revealed in Figure 5.1.

A whole picture of social impact means placing the dual-agent processing mechanism described by Figure 5.3 in a wide social context under the rules of social contagion discussed previously. At the same time, to investigate the dynamics of social impact, it is necessary to place social impact in a scenario where individuals are iteratively exposed to social information and a

Table 5.1: Mappings between a Regular Message and an Interactive Message

General attribute	**Attribute of a regular message**	**Corresponding attribute of an interactive message**
Attitude	Attitude advocated by the message	Attitude maintained by the sender (individual i)
Persuasiveness	Strength and quality of the arguments carried by the message	The prior knowledge of the sender (individual i)
Familiarity	Receiver's perception of familiarity with the message source	The similarity in social presence (e.g., in terms of age, gender, education, occupation, time, space, interest, social status, social category, etc.) between the sender (individual i) and the receiver (individual j)
Credibility	Receiver's perception of the authority and expertise of the message source	The social presence of occupation, social status, social category, influence, etc., of the sender (individual i)
Expression and presentation	Expression and presentation of the message content through a specific medium	The sender (individual i) translates their own attitude, knowledge and social presence into a message, and presents the message to the receiver (individual j) in a specific form, through media or word of mouth

sequence of messages (from media) and during each iteration of exposure, the fundamental social network could be reconstructed, as displayed by Figure 5.4.

By doing that, the effects of information distortion and cognitive biases both at the individual scale and the societal scale resulting from social impact

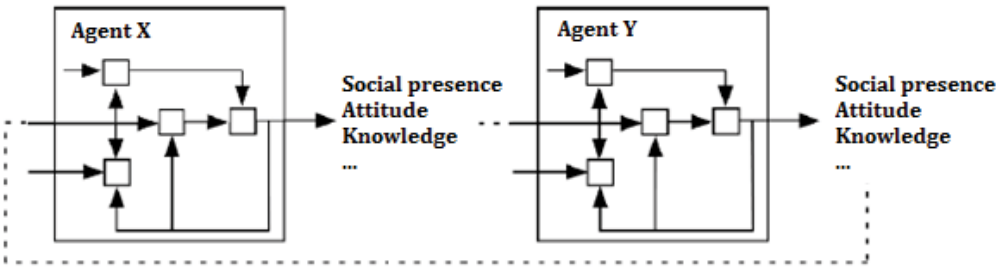


Figure 5.3: The Basic Processing Model of Social Impact between Dual Agents

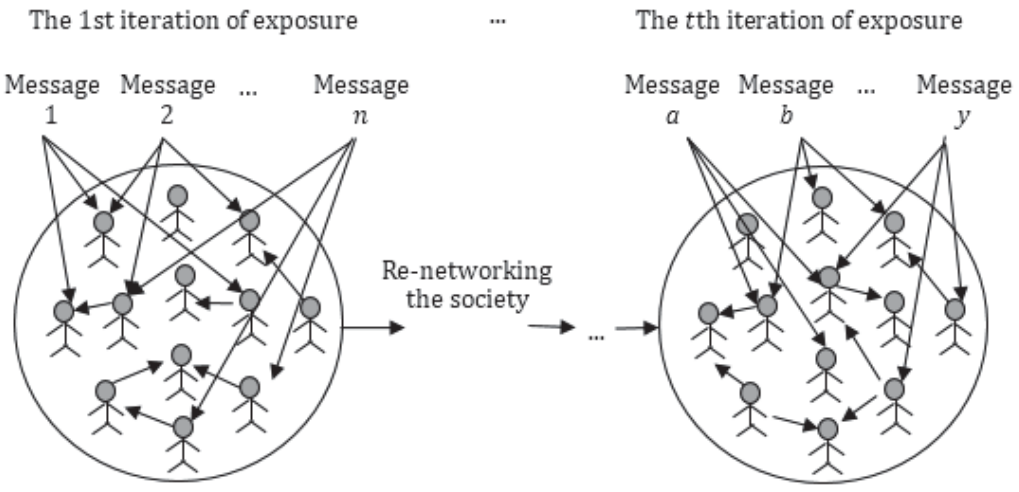


Figure 5.4: Social Impact in the Context of Sequential Exposure to Social Information and Media Messages

can be more precisely portrayed.

5.1.4 Other Accounts

Besides the above design, to more precisely replicate the reality, the current research also take into account the impact of external stimuli on the social evolution. These stimuli typically involve information published on mass media, the overtly diffused scientific knowledge, the influence of opinion leaders, the publicising activities, and so on.

Particularly, two major kinds of external messages are considered:

- **Mass media**. Message communicated on mass media also share the properties defined in Section 5.1.1, i.e., attitude, arguments, and cues. Besides, another two dimensions of mass media are defined. The first dimension is *relevance*, which characterises the level of personal relevance that mass media can technically manipulated. The second dimension is *coverage*, which describes the proportion of audience that mass media can exert their influence.

- **Change agent**. Change agents are persuaders who can adapt their communication strategies in accordance with the characteristics of audience (Mosler & Martens 2008). For example, they provide those individuals who are little motivated or in lack of necessary knowledge with messages full of persuasive cues in a vivid way, or afford those individuals who are less susceptible to these cues but more attentive to substantial content with forceful arguments. Change agents can only influence a small proportion (specified by *coverage*) of audience, but they obviously have great influencing potentials.

5.2 Implementation of Social Computing

5.2.1 Objectives of Social Computing

As we see every minute, a topic, an advocacy, an appeal, or a recent public event always kindle public's attention, especially in nowadays Internet age. People talk, argue, depute with each other, or keep silence. All these behaviours yield specific social outcomes. In this chapter, we bring into the weapon of social computing, seeking to observe the differences in the effects of different social structures and different conditions of dynamics on information distortion and cognitive biases involved in these behaviours at both individual level and societal level, in the following respects:

- Under or not under social impact (networked or not networked);
- Different levels of society cognition states (such as the overall social orientation, public concerns to a target advocacy, general knowledge level, etc.);
- Taking or not taking into account distorted information processing;
- Different degrees of social contacts;
- Different network dynamics;
- Different states of individual heterogeneity;
- Including or not including the impact of mass media;
- Including or not including the impact of change agents;
- The interplays of the above parameters of social impact.

In addition, the mystery of the emergent effects from private attitude to public opinions is also an important aspect the current research attempts to unveil, since these emergent effects are essentially the outcomes of information distort and cognitive biases at the society/system scale. For examining

these emergent effects, the discussions of Nowak et al. (1990) prepare a start point: whether the null hypothesis insisted by most social psychologists, that groups would move toward uniformity of opinion, as individuals converge on the most common viewpoint, really holds true under social impact? In other words, whether the processes of social impact themselves result in the uniformity of attitude and opinion and whether the processes of social impact lead to the convergence of public opinion on the mean of the initial distribution of private attitudes? In the spirit behind these reflections, the simulation experiments in the current research will measure the departure of social attitudes after social impact processes from the mean of the initial attitudes of individuals and delve into the drivers of this departure.

5.2.2 Structure of the Social Simulator

Figure 5.5 displays the sequence diagram of the social simulator implemented as per the previous research design, which presents the inner structure of the simulator.

5.2.3 Interfaces of the Social Simulator

Figure 5.6 shows the main form of the social simulator, which provides the entry for inputting the parameters associated with the computing. Figure 5.7 presents the form for editing the properties of external influencing sources, including mass media and change agents. In Figure 5.8 is the graphical displayer of computing outcomes. Besides, the procedural data as well as the results data are output to textual files, providing extra information for analysis and discussions.

Note, as can be see from Figure 5.8 (b) and 5.9(c)(d), in order to observe the evolution of social effects from the starting point, the individuals in the computing setting are grouped into two classes, in terms of their initial attitudes prior to all evolving iterations, as follows:

- **Right**. All the individuals whose initial attitudes are positive (i.e.,

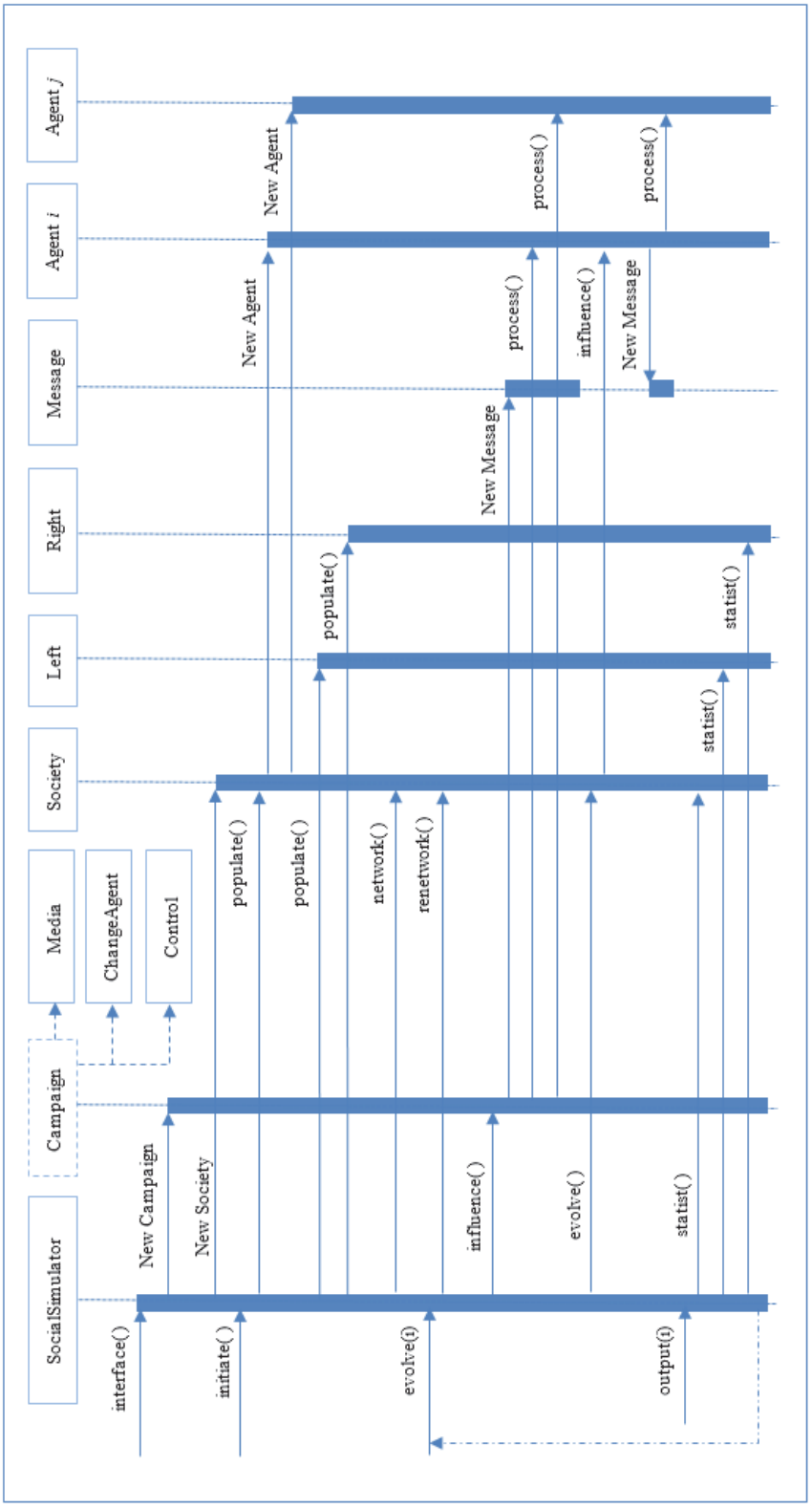


Figure 5.5: Sequence Diagram of the Social Simulator

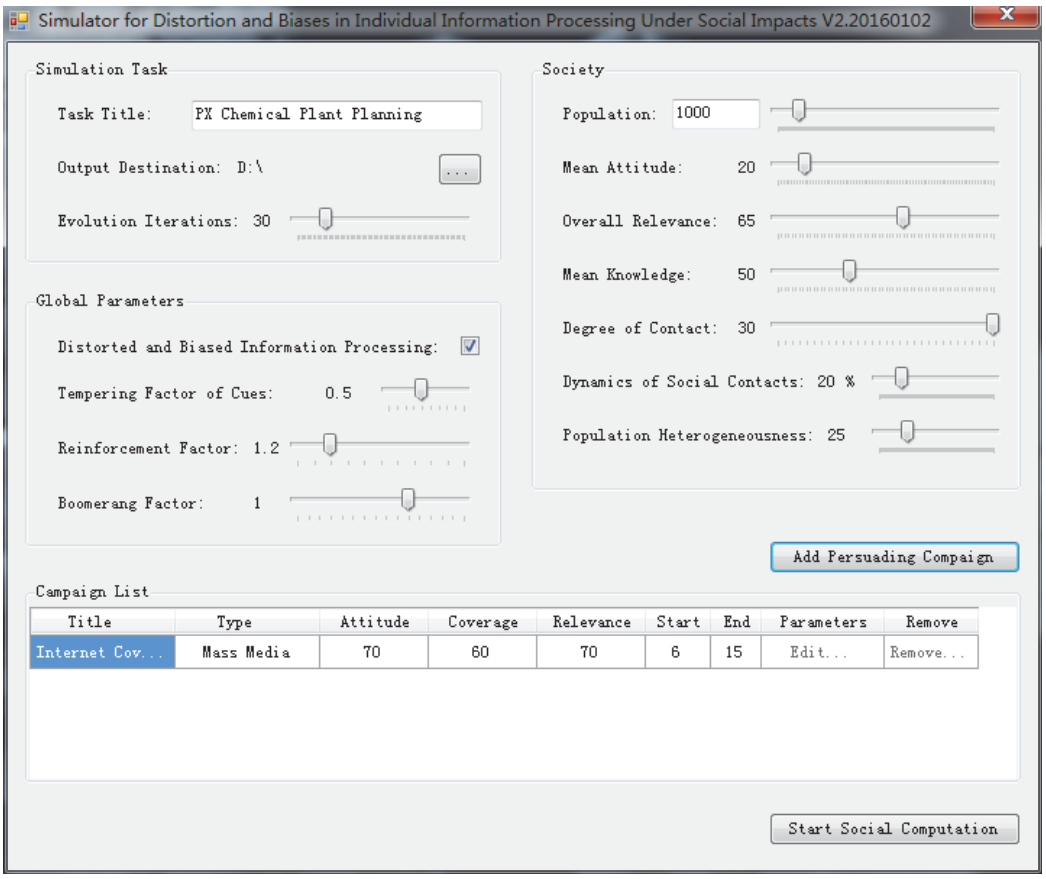


Figure 5.6: The Main Form of the Social Simulator

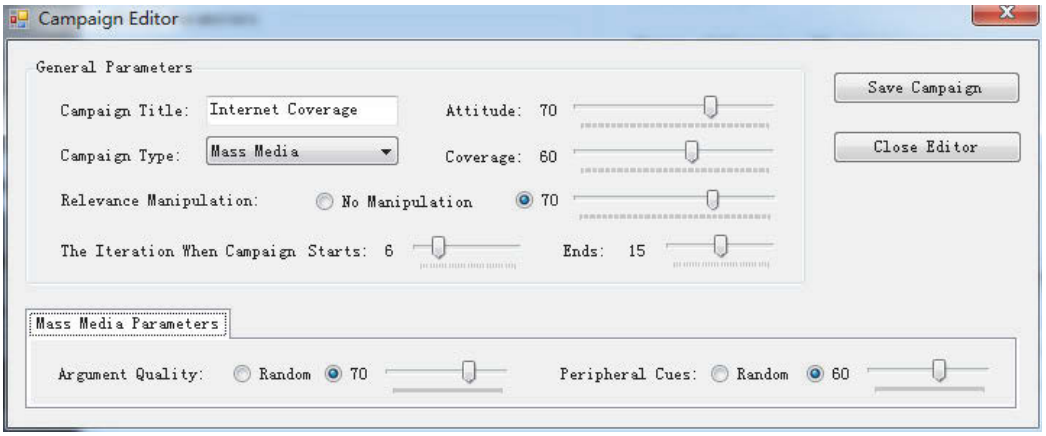
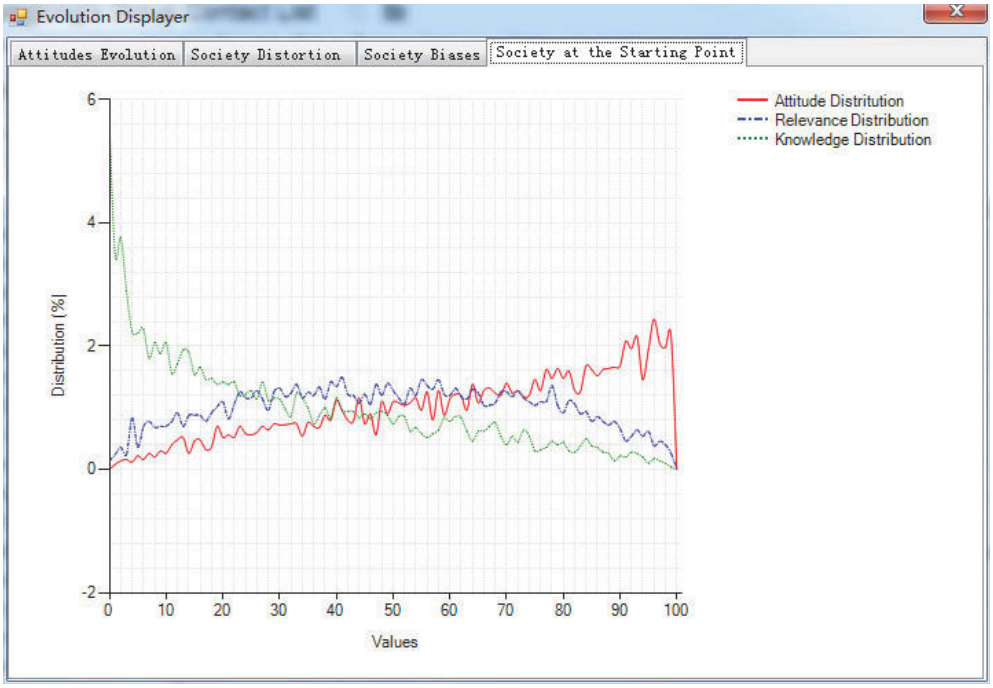
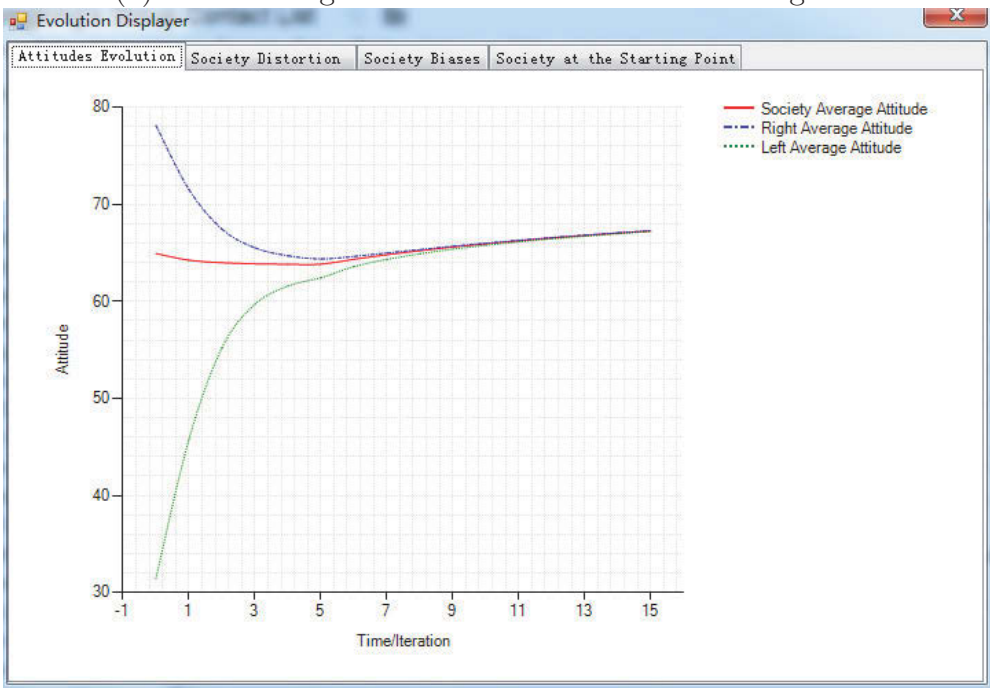


Figure 5.7: The Editing Form for External Influencing Sources

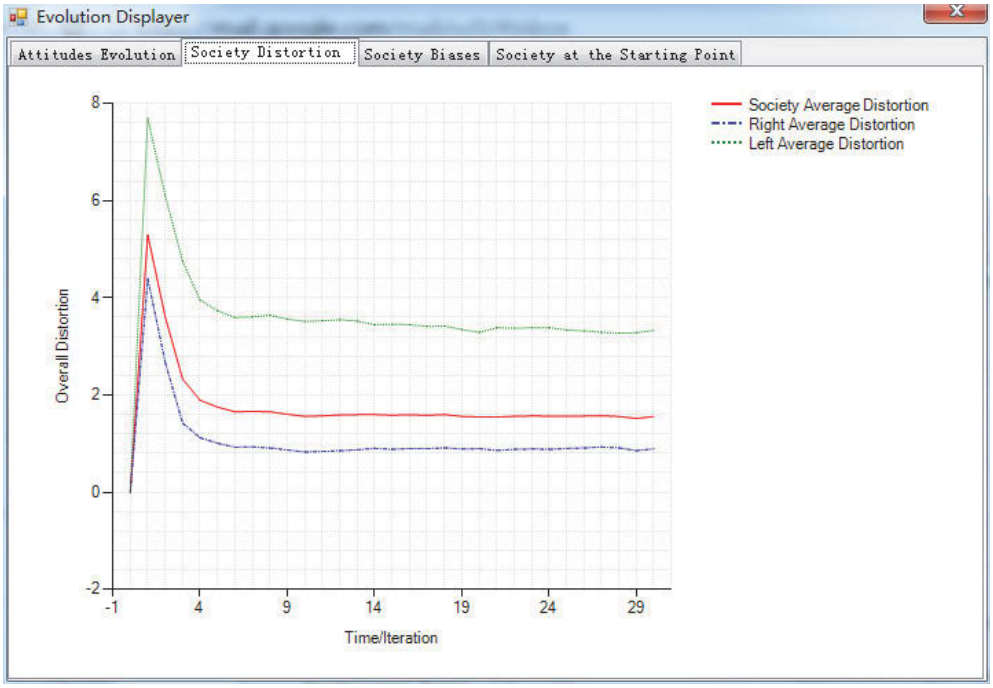


(a) Societal Cognition Distribution at the Starting Point

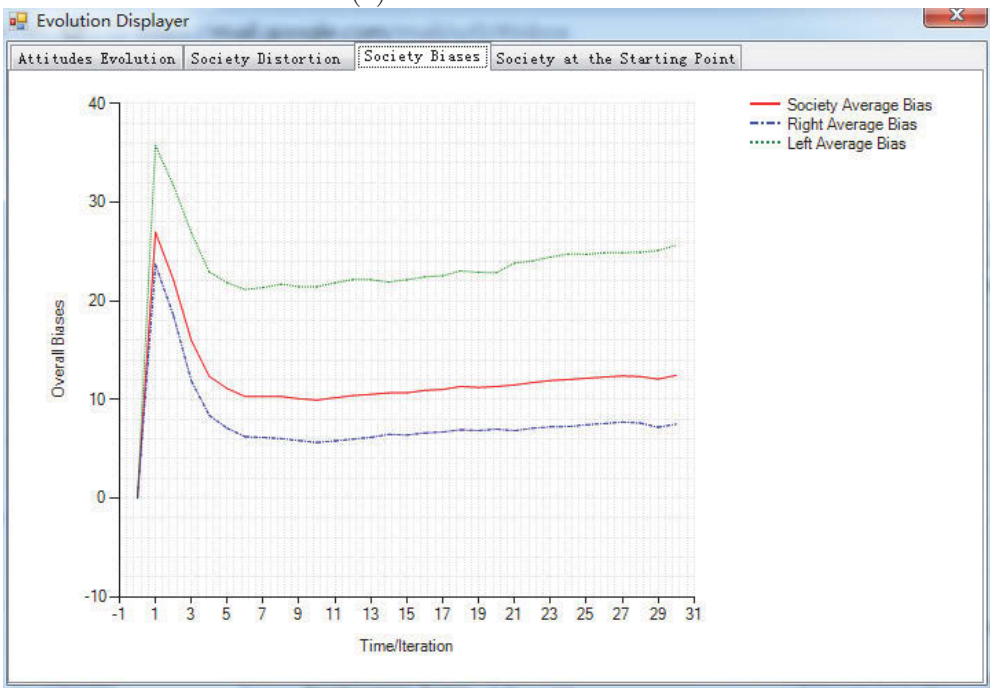


(b) Attitude Evolution

Figure 5.8: The Displayer for Social Computing Outcomes



(c) Societal Distortion



(d) Societal Biases

Figure 5.9: The Displayer for Social Computing Outcomes (Cont.)

greater than the neutral point 50) towards the advocacy assumed in the computing setting are labeled as *right*.

- **Left**. The other individuals whose initial attitudes are negative (i.e., equal or less than 50) towards the advocacy are marked as *left*.

The computing outcomes corresponding to the *right* group are indicated as blue dashed lines in the associated curves, the indicators of *left* group are drawn with green dot lines, whereas the entire society is illustrated with red solid lines.

5.2.4 Initialising Social Computing

There definitely involves initialising work before the social computing is substantially executed. For the subsequent analyses and discussions, some initialising processes need to be clarified, as follows:

- **Populating the society**. In the current research, $5,000$ agents are populated in terms of the size, the mean attitude, the overall relevance (of the advocacy to the individuals), the average knowledge level, and the heterogeneity of the society. When randomly producing an agent, most properties are randomly assigned by normal sampling. Sampling a number from normative distribution within a scale of $[0, 100]$ entails a expectation of 50. For a society with mean attitude, overall relevance, average knowledge often not located on the point 50, this sampling is really tricky. For these properties, the current research randomly sample numbers from Beta distributions, by estimating the required parameters, i.e., α, β, in the following way:

$$\alpha = \mu \left(\frac{\mu (1 - \mu)}{\sigma^2} - 1 \right) \tag{5.14}$$

$$\beta = (1 - \mu) \left(\frac{\mu (1 - \mu)}{\sigma^2} - 1 \right) \tag{5.15}$$

where μ denotes the mean or expectation, and σ represents the standard deviation, which is decided by the parameter of heterogeneity.

Figure 5.8 (b) shows the actual distribution of attitude (with a mean 65 and a standard deviation 25), relevance (mean 50 and standard deviation 25), and knowledge (mean 30 and standard deviation 25) of the society at the starting point, from which it is sensible to say that Beta distribution offers a powerful way for asymmetric truncated sampling.

- **Processing the heterogeneity**. As mentioned above, the current research deals with individual heterogeneity by setting a common standard deviation (set by the global parameter) of the distribution for those heterogeneity-related properties. A higher standard deviation means greater heterogeneity.

- **Networking the society**. The society are networked by randomly as per the parameter of overall connecting degree. In other words, the social networks in the current research are random networks of specific degrees.

- **The influence power of individuals**. As explained in Section 5.1.3, the interaction between two individuals can be interpreted as one individual sends to the other one a message advocating an attitude and the latter processes the message. Therefore, the properties of the sender will be mapped to the attributes of a message, as described in Table 5.1. To model the *cues* that an individual shows to others, an attribute named *impact* is appended to the data of an individual (agent). This attribute characterises the influencing power of the individual. The amount of cues associated with an agent is a function of its impact and its knowledge.

5.3 Results and Discussions

As per the objectives of social computing claimed in Section 5.2.1, the simulating results are discussed as follows.

5.3.1 Cognitive Effects Under versus Not Under Social Impact

Figure 5.10 compares the attitude evolutions in a society setting of mutually interacting individuals and a setting without mutual impact.

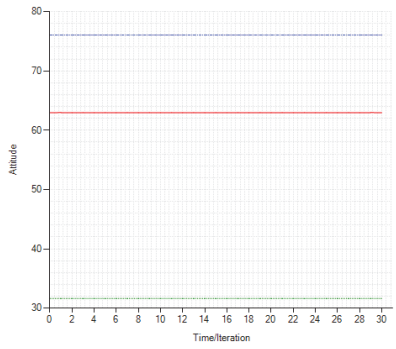
It is obvious that without interacting with others, people keep silence and isolated, maintaining stable attitudes. When people interplay with connected others, their attitude alter.

Notes below Figure 5.10 and the panels give the naming of the associated parameters. In later sections, these parameters are denoted as the abbreviations. Also the symbols for these parameters are listed in Table 5.2 to ease the understanding of the following sections.

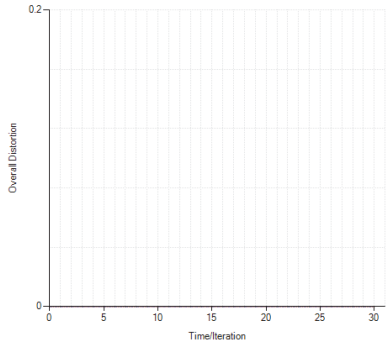
5.3.2 Effects of Overall Societal Cognition States

The effects of the average society orientation (parametrised as mean attitude), public concerns to a target information processing context (overall relevance), the society cognitive capability (mean knowledge) on the evolution of social attitude are pictured in this section.

Figure 5.11 juxtaposes the attitude evolutions in different societies with different prior attitudes. It can be inferred that, when the whole society manifests a skew towards an extreme (e.g., 10 and 90, see panel (a) and (f)), the substantial majority stand together in high agreements, and their attitudes soon polarise. Those limited dissenters who feel isolated and severe dissonance with the majority will champion their positions in a strongly distorted way. Figure 5.12 provides extra evidence for this situation where people are tightly gathering. With the moderating of this extreme situation,

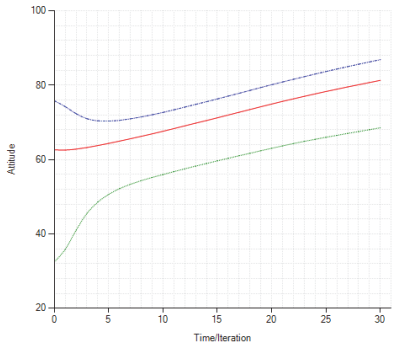


(a) Attitude Evolution

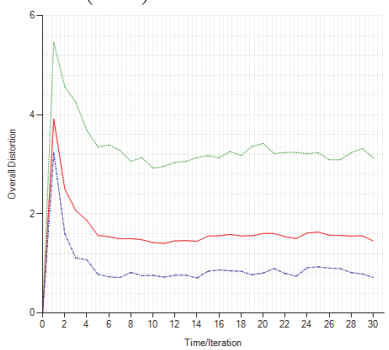


(b) Societal Distortion

No Social Impact: Degree of contact (DC) = 0



(c) Attitude Evolution



(d) Societal Distortion

Under Social Impact

Degree of contact (DC) = 20; Dynamics of social contacts (DY) = 20%

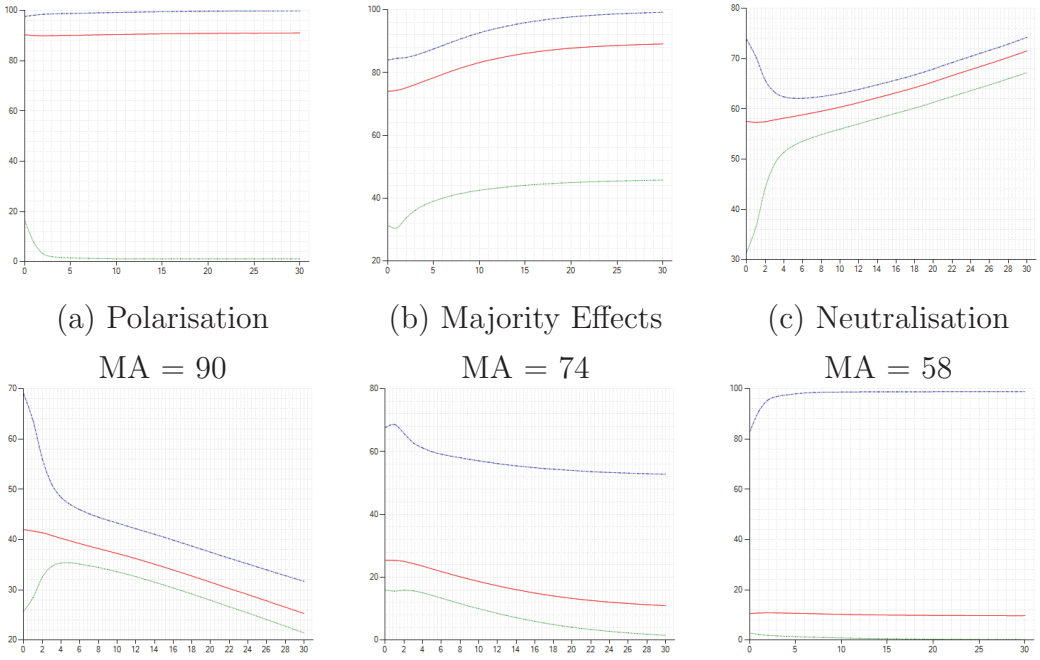
Figure 5.10: Attitude Effects Under versus Not Under Social Impact Parameters: Mean attitude (MA) = 62; Overall relevance (MR) = 62; Mean knowledge (MK) = 62; Population Heterogeneity (PH) = 25; Tempering factor of cues (α) = 0.2; Reinforcement factor (γ) = 1.2; Boomerang factor (λ) = 0.2; Distorted Processing; Iterations (IT) = 30.

Table 5.2: Symbols (Abbreviations) for Social Computing Parameters

Symbol(Abbreviation)	**Description**
DC	Degree of Contact
DY	Dynamics of Social Contacts
MA	Mean Attitude
MR	Mean Revelance
MK	Mean Knowledge
PH	Population Heterogeneity
α	Tempering Factor of Cues
γ	Reinforcement Factor
λ	Boomerang Factor
IT	Iterations

the polarisation tempers. When a majority dominates the minority (as shown in panel (b) and (e)), the former convert the latter while consolidating their own places. Further when there mixes with two matching opposite forces (panel (c) and (d)), the effects of neutralisation or negotiation govern the evolution of attitudes, the overall value of the society may converge to a point. The above outcomes provides the explanatory evidence for many persuading and discussion scenarios.

Although there seems no significant trend in the effects of relevance manipulation, we can still infer from Figure 5.13 that when an advocacy is critical to public benefits (e.g., MR=90, see panel (a)), people are willing to carefully synthesise social information and make a rational sense, leading to a possibility of social convergence, whereas when the topic (e.g., an entertaining event, see panel (b)) is just trivial for concerns, they tend to ignore the social information and disregard others' tastes.



(a) Polarisation MA = 90 (b) Majority Effects MA = 74 (c) Neutralisation MA = 58

(d) Neutralisation MA = 42 (e) Majority Effects MA = 26 (f) Polarisation MA = 10

Figure 5.11: Attitude Effects of Different Overall Societal Orientations Parameters: MR = 62; MK = 62; DC = 20; DY = 20%; PH = 20; $\alpha = 0.3$; $\gamma = 1.2$; $\lambda = 0.2$; IT = 30.

Note, the current research regards the knowledge and impacting power of individuals as cues for others' perceptions. Therefore, behind the figure, there is a complicated relationship. However, it is still not that difficult to comprehend the effects of knowledge from Figure 5.14. When a community shares a high level of knowledge (MK=90, panel (a)), the members are more influential to each other, and they possess higher capabilities to reasoning, therefore, their ultimate cognitive states will moves to the side of majority where most expert stand. By contrast, when people are ignorant to a proposal (MK=10, panel(f)), they lack the rationality as well as the potential to influence others, and they are easy to agree with each other in a shallow way, leading to a relatively neutralised social orientation.

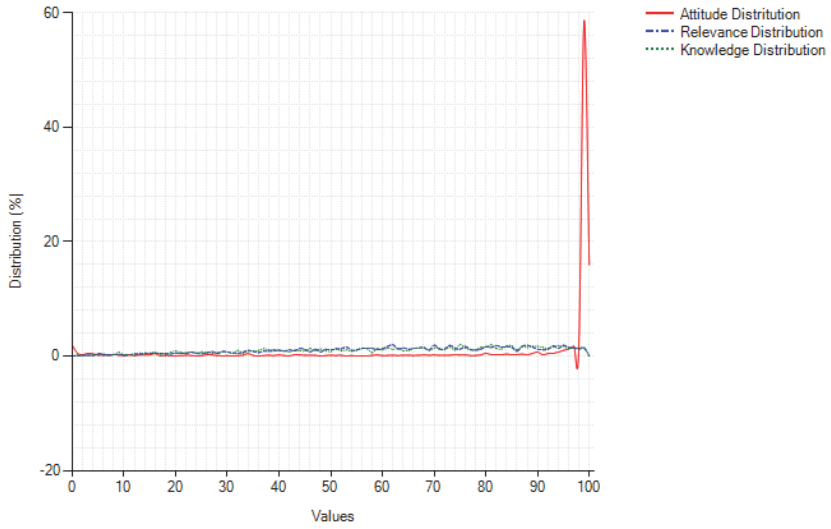
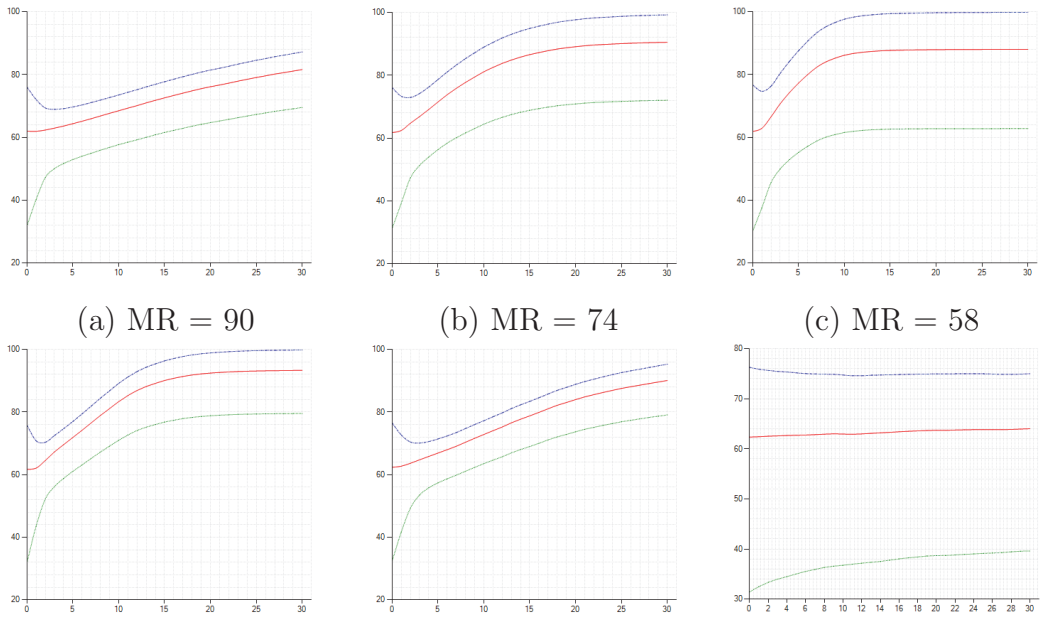


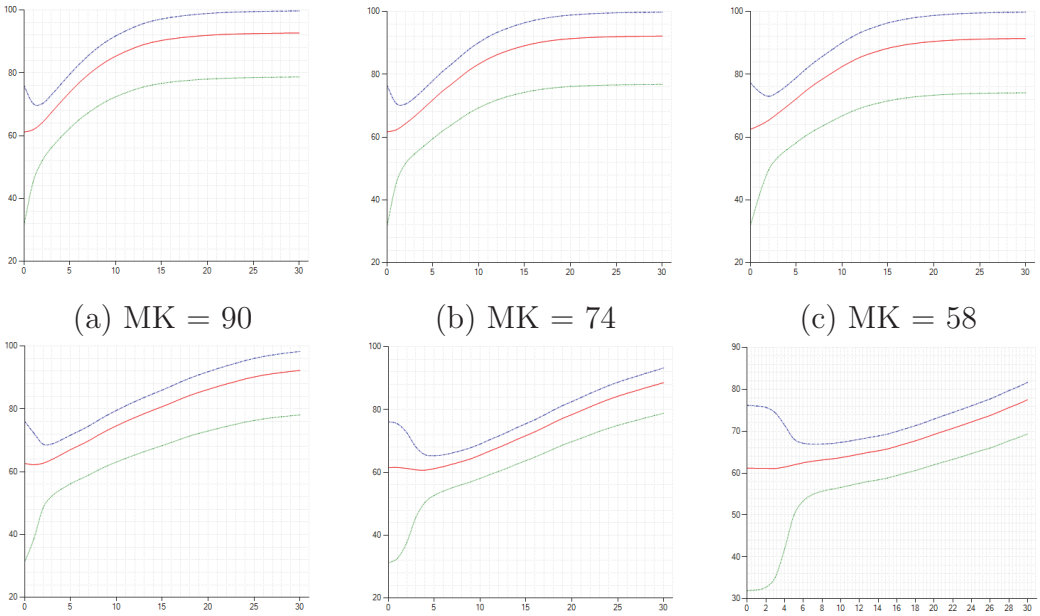
Figure 5.12: Distribution of Initial Societal Attitudes When the Overall Orientation is Extreme



(a) MR = 90 (b) MR = 74 (c) MR = 58

(d) MR = 42 (e) MR = 26 (f) MR = 10

Figure 5.13: Attitude Effects of Different Public Concerns
Parameters: MA = 72; MK = 62; DC = 20; DY = 20%; PH = 25; $\alpha = 0.8$; $\gamma = 1.2$; $\lambda = 0.2$; IT = 30.



(a) MK = 90 (b) MK = 74 (c) MK = 58

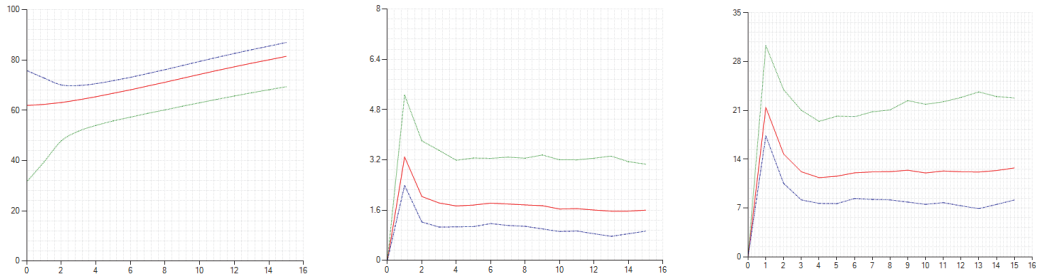
(d) MK = 42 (e) MK = 26 (f) MK = 10

Figure 5.14: Attitude Effects of Different Societal Knowledge Levels Parameters: MA = 72; MR = 62; DC = 20; DY = 15%; PH = 25; $\alpha = 0.8$; $\gamma = 1.2$; $\lambda = 0.2$; IT = 30.

5.3.3 Social Effects Involving versus Not Involving Distorted Information Processing

Figure 5.15 contrasts the social effects in two settings, with one involves distorted processing and the other excludes the distorted way. Attitude variations, the amount of distortion and biases are illustrated for the two settings. It is not surprising that there are no substantial distortion and biased in the distortion-excluded settings, or if there are, it is resulted from the measures of distortion and biases (see Equation 3.9 and 3.10 for distortion measurement and Equation 5.13 for bias measurement). The most interesting point is the attitude evolution in the distortion-excluded settings. It presents to-the-point answers for the questions asked by Nowak et al. (1990): whether social impact itself lead to the uniformity and convergence of public cognition to the average point of the initial private cognitions? Definitely, as per our computing outcomes, this null hypothesis a asserted by most social psychologists only holds true in the condition where individuals will not distort the social information presented to them. However, this is hardly true, according to the facts behind Figure 5.15 (b1-b3). It is a long way (or even no way) to reach the uniformity and convergence, and there are substantial distortion and biases especially for the minority party (the upper green in panel (a2) and (a3).

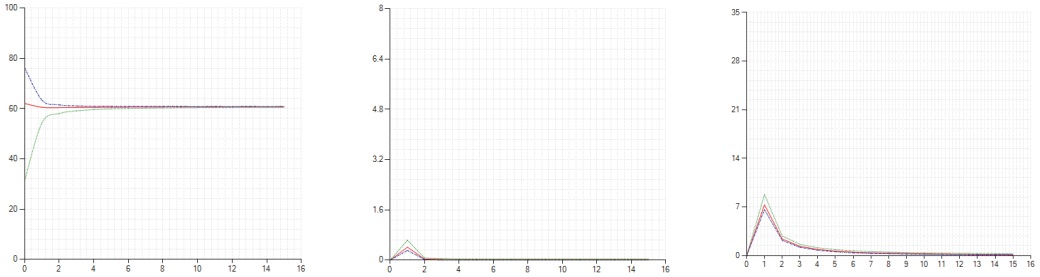
Now, we move to discussing the effects of three parameters associated with distorted processing. The first one is the tempering factor, α, defined in Equation 5.7, which determines how much an individual will choose the heuristic route to processing the peripheral cues (Petty & Cacioppo 1986). However, the results, as illustrated in Figure 5.16, challenge our intuition: along with the decrease of α, distortion and biases rise. This raise an interesting issue for further investigation. However, at the current stage, this is still justifiable: since the peripheral factor defined in Equation 5.5 distinguishes useful cues from inconsequential or even negative ones, the sense an individual learned by cues therefore constitutes an important informative part indispensable for their judgement. Artificially ignoring this part



(a1) Attitude Evolution (a2) Amount of Distortion (a3) Amount of Biases

$\alpha = 0.5$; $\gamma = 1.2$; $\lambda = 0.5$

Involving Distorted Processing



(b1) Attitude Evolution (b2) Amount of Distortion (b3) Amount of Biases

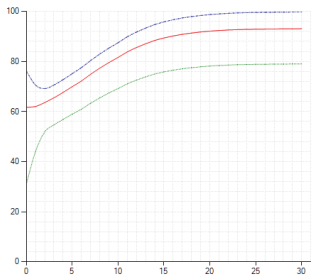
Not Involving Undistorted Processing

Figure 5.15: Social Effects Involving versus Not Involving Distorted Information Processing

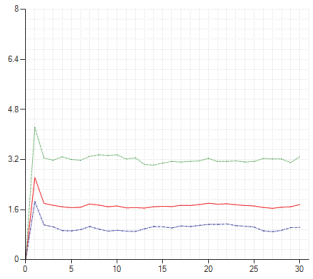
Parameters: MA = 62; MR = 62; MK = 62; DC = 20; DY = 20%; PH = 25; IT = 15.

will unavoidably incur more distortion and bias in their assessment. This computing result hence offers the opportunity for us to improve our model design.

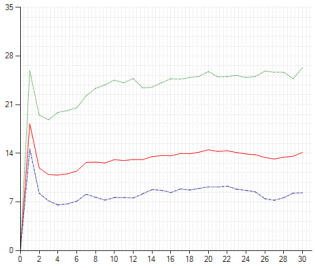
The second parameter is the reinforcement factor, γ, incorporated into Equation 5.9, characterising the extent to which an individual will assimilate the sense from the social information to consolidate or even reinforcement their attitude establishment. The basic trend implied in Figure 5.17 confirms the assumption of reinforcement: when people with relatively lower cognitive dissonance (i.e., <= 50, see Equation 5.9), they are willing to integrate the inconsistent information into their attitude, therefore, a greater γ leads to



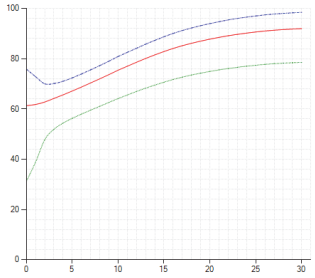
(a1) Attitude Evolution $\alpha = 1$



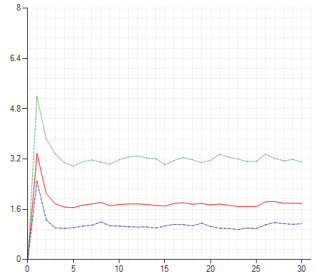
(a2) Amount of Distortion $\alpha = 1$



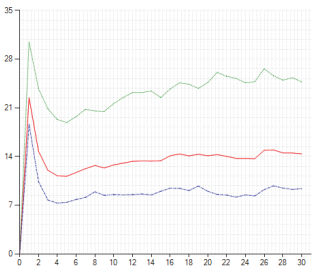
(a3) Amount of Biases $\alpha = 1$



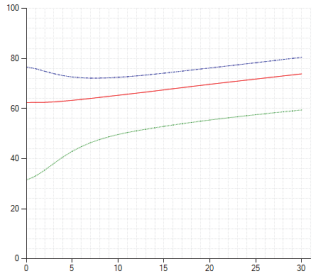
(b1) Attitude Evolution $\alpha = 0.5$



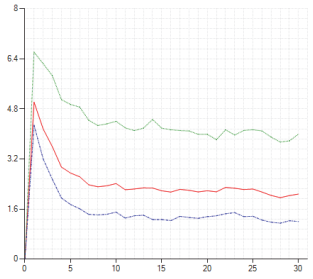
(b2) Amount of Distortion $\alpha = 0.5$



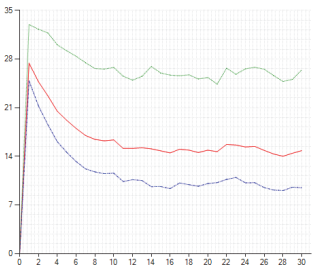
(b3) Amount of Biases $\alpha = 0.5$



(c1) Attitude Evolution $\alpha = 0.1$



(c2) Amount of Distortion $\alpha = 0.1$



(c3) Amount of Biases $\alpha = 0.1$

Figure 5.16: The Effects of Cues Tempering Factor on Information Distortion Parameters: MA = 62; MR = 62; MK = 62; DC = 20; DY = 20%; PH = 25; $\gamma = 1.2$; $\lambda = 0.2$; IT = 30.

smaller distortion and smaller biases. The attitude evolution also tells, by integrating more inconsistent information, the majority further secures their position, while the minority gradually approaches to the majority.

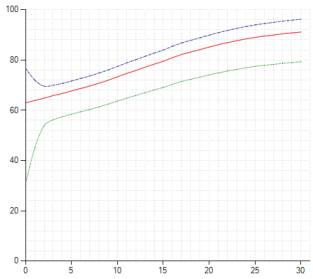
The third parameter is the boomerang factor, λ, also defined in a contingent process in Equation 5.9, featuring the possible behaviour that an individual encountering substantial cognitive dissonance with the social information will stand away from the interaction goal, by resistance and counterarguing. The trend implied in Figure 5.18 justifies this assumption of boomerang effect.

5.3.4 Effects of Social Contact Degree

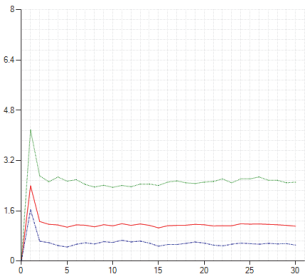
A highly interconnected society entails active and frequent exchanges among the members, leading to intensive changes in social states. We test this assumption in a balanced society whose overall position is neutral, and see whether a quicker convergence happens in a more connected society. Figure 5.10 offers the first evidence for this sense. More detailed variations can be seen in Figure 5.19. Interesting, the more interconnected a society is, the less distortion and biases happen, and when social cognition converges, the distortion and biases therefore disappear, due to the reached agreement.

5.3.5 Effects of Social Structure Dynamics

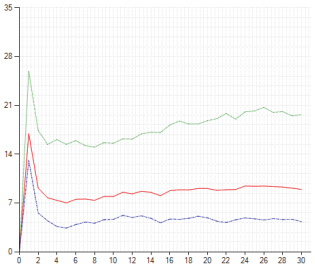
A fluid society entails active and frequent exchanges among the reshuffling members, leading to more efficient changes in social states. We use the percentage of discarded connections as well as new incoming contacts in each computing iteration as the measure of social dynamics. Figure 5.20 presents the comparison of social effects at different levels of dynamics, which contains slight hints for the associated assumptions.



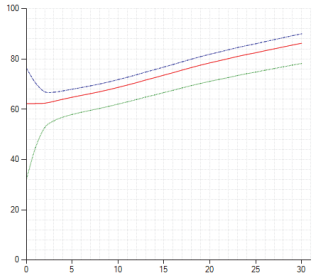
(a1) Attitude Evolution $\gamma = 2.0$



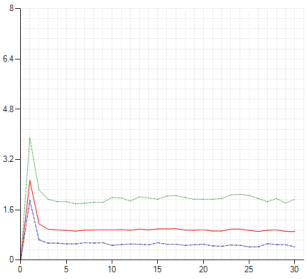
(a2) Amount of Distortion $\gamma = 2.0$



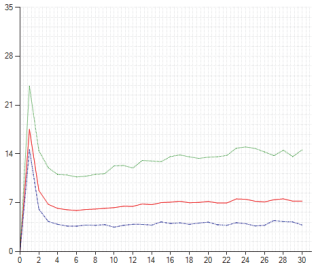
(a3) Amount of Biases $\gamma = 2.0$



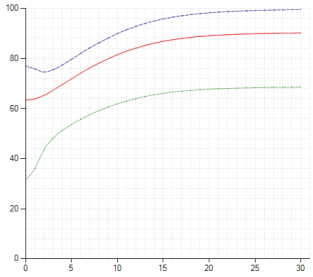
(b1) Attitude Evolution $\gamma = 1.5$



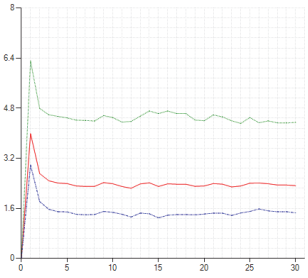
(b2) Amount of Distortion $\gamma = 1.5$



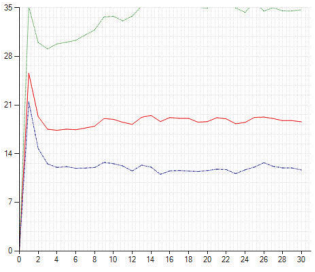
(b3) Amount of Biases $\gamma = 1.5$



(c1) Attitude Evolution $\gamma = 1.0$

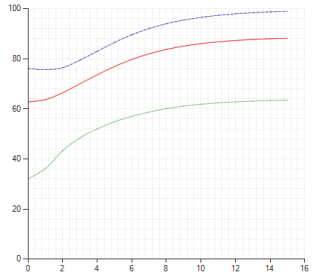


(c2) Amount of Distortion $\gamma = 1.0$

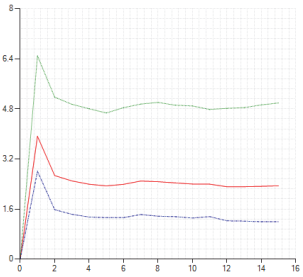


(c3) Amount of Biases $\gamma = 1.0$

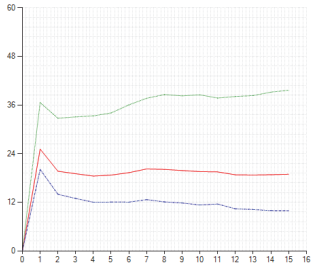
Figure 5.17: The Effects of Reinforcement Factor on Information Distortion Parameters: MA = 62; MR = 62; MK = 62; DC = 20; DY = 20%; PH = 25; $\alpha = 0.5$; $\lambda = 0.2$; IT = 30.



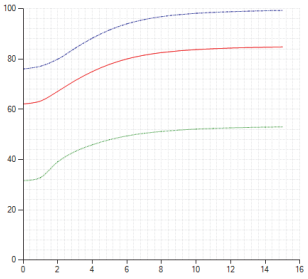
(a1) Attitude Evolution $\lambda = 1.5$



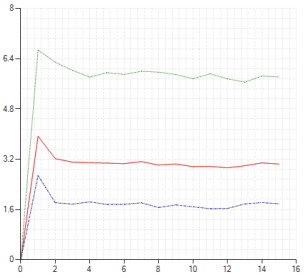
(a2) Amount of Distortion $\lambda = 1.5$



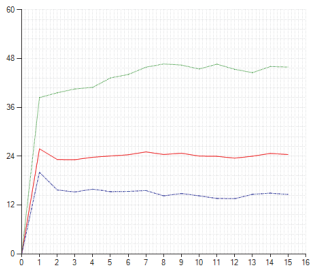
(a3) Amount of Biases $\lambda = 1.5$



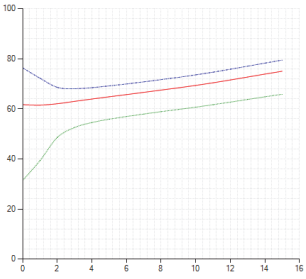
(b1) Attitude Evolution $\lambda = 0.8$



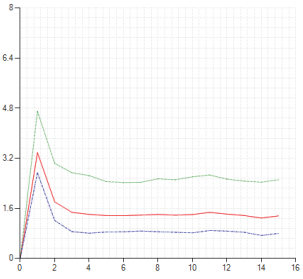
(b2) Amount of Distortion $\lambda = 0.8$



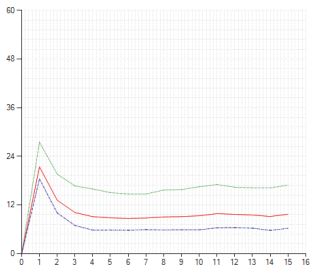
(b3) Amount of Biases $\lambda = 0.8$



(c1) Attitude Evolution $\lambda = 0.1$

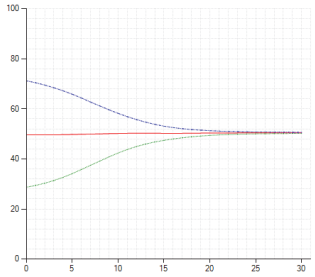


(c2) Amount of Distortion $\lambda = 0.1$

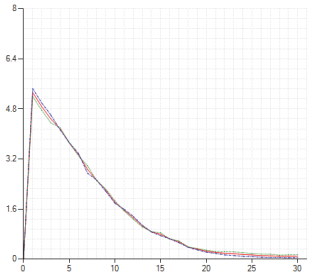


(c3) Amount of Biases $\lambda = 0.1$

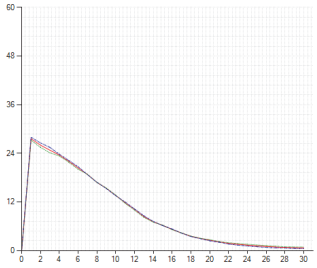
Figure 5.18: The Effects of Boomerang Factor on Information Distortion Parameters: MA = 62; MR = 62; MK = 62; DC = 20; DY = 20%; PH = 25; $\alpha = 0.5$; $\gamma = 1.2$; IT = 30.



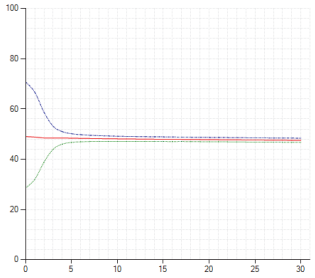
(a1) Attitude Evolution DC = 5



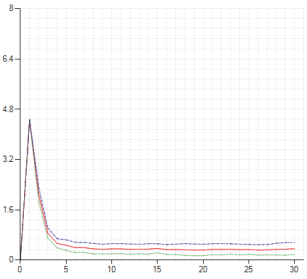
(a2) Amount of Distortion DC = 5



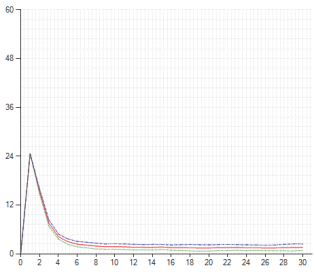
(a3) Amount of Biases DC = 5



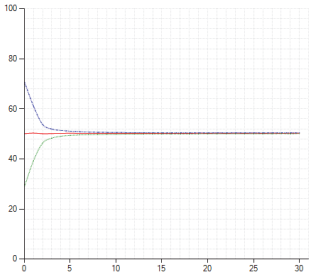
(b1) Attitude Evolution DC = 18



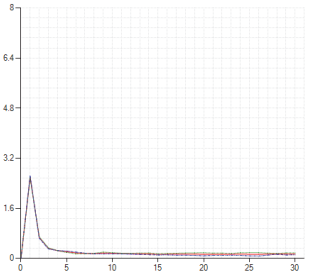
(b2) Amount of Distortion DC = 18



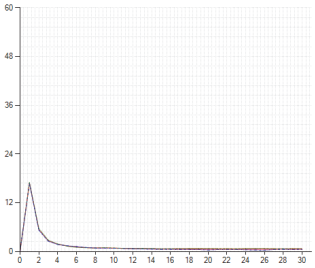
(b3) Amount of Biases DC = 18



(c1) Attitude Evolution DC = 30



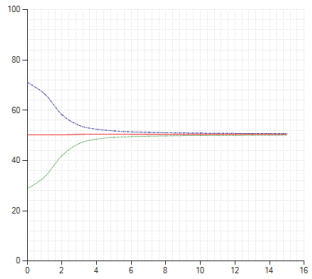
(c2) Amount of Distortion DC = 30



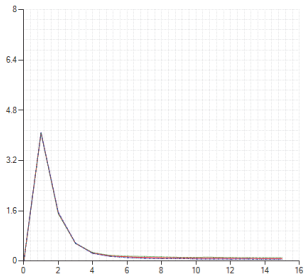
(c3) Amount of Biases DC = 30

Figure 5.19: The Effects of Social Contact Degree

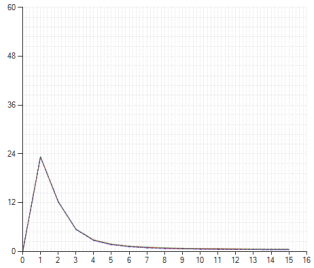
Parameters: MA = 50; MR = 50; MK = 50; DY = 20%; PH = 25; $\alpha = 0.5$; $\gamma = 1.2$; $\lambda = 0.2$; IT = 30.



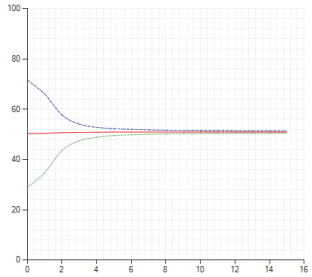
(a1) Attitude Evolution DY = 10%



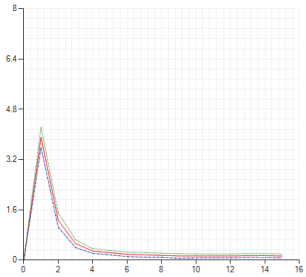
(a2) Amount of Distortion DY = 10%



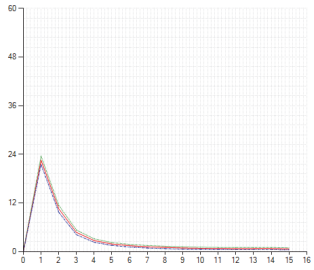
(a3) Amount of Biases DY = 10%



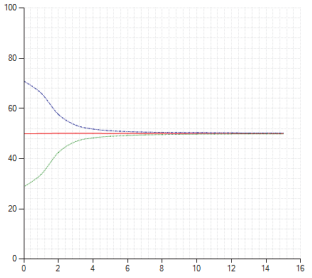
(b1) Attitude Evolution DY = 25%



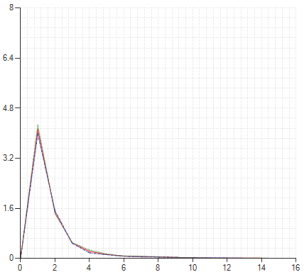
(b2) Amount of Distortion DY = 25%



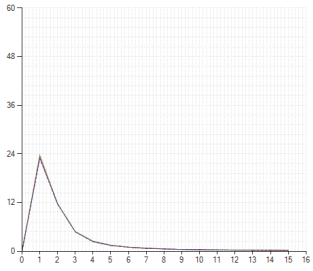
(b3) Amount of Biases DY = 25%



(c1) Attitude Evolution DY = 40%



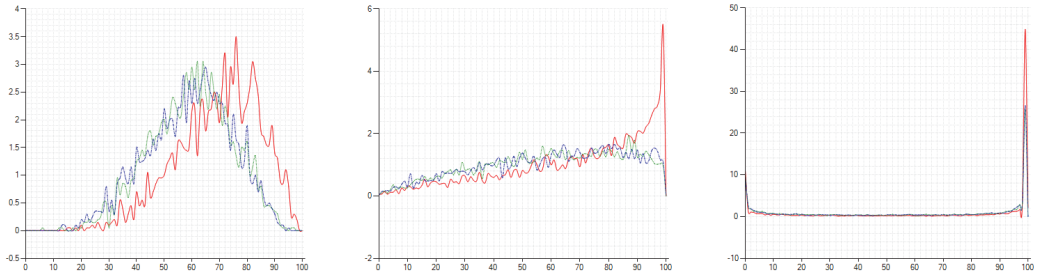
(c2) Amount of Distortion DY = 40%



(c3) Amount of Biases DY = 40%

Figure 5.20: The Effects of Social Structure Dynamics

Parameters: MA = 50; MR = 50; MK = 50; DC = 20; PH = 25; $\alpha = 0.5$; $\gamma = 1.2$; $\lambda = 0.2$; IT = 30.



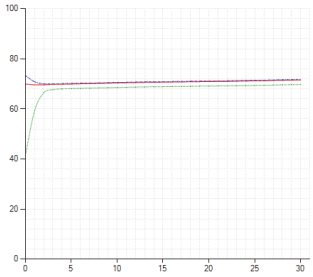
(a) PH = 15 (b) PH = 25 (c) PH = 40

Figure 5.21: The Effects of Heterogeneity on Social Cognition Distribution Parameters: MA = 70; MR = 50; MK = 50; DC = 20; DY = 20%; $\alpha = 0.5$; $\gamma = 1.2$; $\lambda = 0.2$; IT = 30.

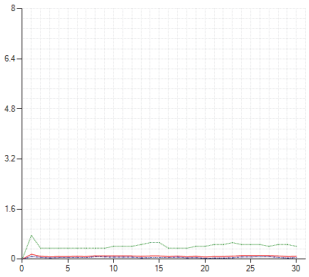
5.3.6 Effects of Population Heterogeneity

Heterogeneity is a nature of difference societies. It depicts the difference in the demographic, mental and behavioural properties and presences of the members in a society. People tend to approach those others who share commonalities with themselves. In the current research, Heterogeneity among the interacting pairs of individual widen their mutual cognitive dissonance, knowledge gaps, and the distance between their impacting potentials.

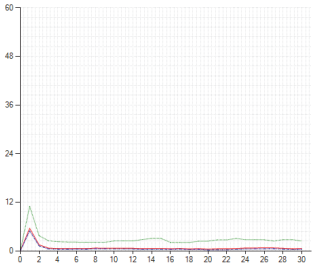
As discussed previously, technically, we treat heterogeneity as the standard deviation of the distribution of agent properties. A greater heterogeneity lead to more significant variations in the sampled values with regard to a specific property. Figure 5.21 shows the effects of different heterogeneity settings to the distribution of initial states of attitude, relevance and knowledge of a society. Lower heterogeneity leads to a relatively smooth normal-like distribution, whereas greater heterogeneity leads to a polarised U-shape distribution. The different distributions result in a different attitude evolution outcomes, as well as different ways of distortion and biased processing. As indicated in Figure 5.22, a homogeneous society is more likely to reach a uniformity and convergence, whereas a heterogeneous society is more likely to end up with chaos, antagonism, and polarisation. These findings deserves intensive attentions.



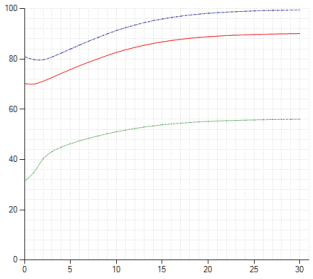
(a1) Attitude Evolution PH = 15



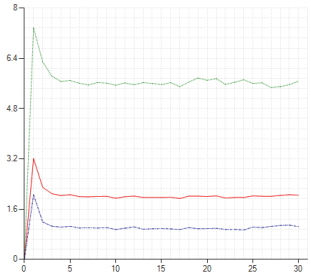
(a2) Amount of Distortion DY = 15



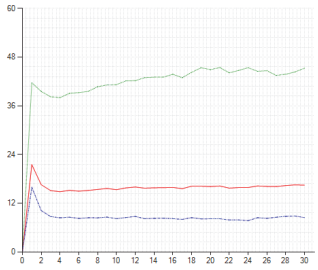
(a3) Amount of Biases DY = 15



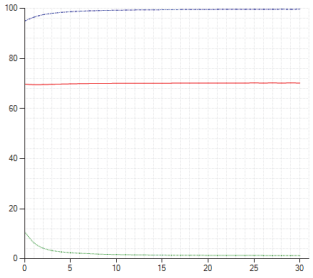
(b1) Attitude Evolution PH = 25



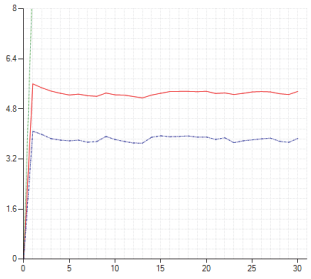
(b2) Amount of Distortion PH = 25



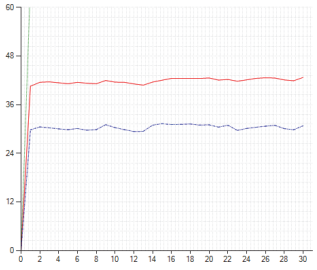
(b3) Amount of Biases PH = 25



(c1) Attitude Evolution PH = 40



(c2) Amount of Distortion PH = 40



(c3) Amount of Biases PH = 40

Figure 5.22: The Effects of Population Heterogeneity

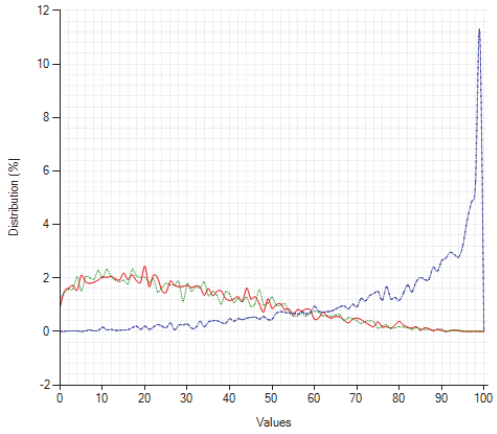
Parameters: MA = 70; MR = 50; MK = 50; DC = 20; DY = 20%; $\alpha = 0.5$; $\gamma = 1.2$; $\lambda = 0.2$; IT = 30.

5.3.7 Impact of External Influence Sources

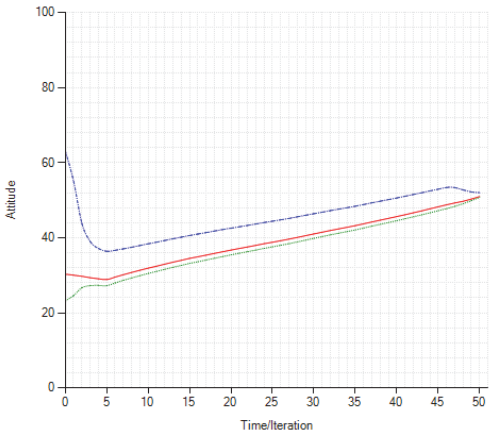
The above analysis mainly concerns the social impact on interconnected individuals. In the actual world, individuals are often exposed to external influencing information sources, such as mass media, lectures, promotions, and other kinds of persuasive campaigns, while exchanging with people surrounding. These campaigns interplay with communicative social information, facilitate or suppress their cognition. The current research incorporates two kinds of external campaigns, i.e., mass media, and selling-like change agents who adapts their persuasion strategies as per the status of audience. Suppose the public takes a relatively negative place towards an chemical plant plan due to the worry of its possible dangers and harms. And the public have limited knowledge regarding the plan and the chemical products. However, this plant is of great economic value for a developing region. The plant is supposed to locate in a region strictly in alignment with the associated regulations and laws, and the operator of the plant have sufficient ability to guarantee it being all safe to the public. So the mass media and persuading agents assumes the responsibility to *intervene* and to nurture a positive position in the public towards the plan. Now let's see what happens.

The settings for the population in the region are described as follows: populations = 5000 (nearly 5000 people live in the region); MA = 30 (the public mostly maintain a negative attitude towards the plan); MR = 50 (they perceive the issue are of great relevance to their lives); MK = 30 (they have poor knowledge); DC = 30 (they live in an highly connected way); DY = 20% (they regularly make new friends); PH = 20 (they share many common things).

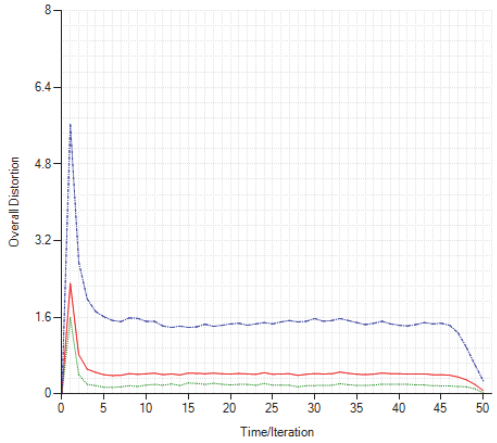
The settings for local mass media are as follows: attitude = 60 (the mass media are absolutely favour the plan, but the articulate in a relatively humble way; this is very important); coverage = 80 (80% of public are covered or influenced by the media); arguments = 70 (The media marshal high-quality arguments regarding the issue); cues = 70 (The media has good prestige, and they mention many authorities and influential figures in their reports); and



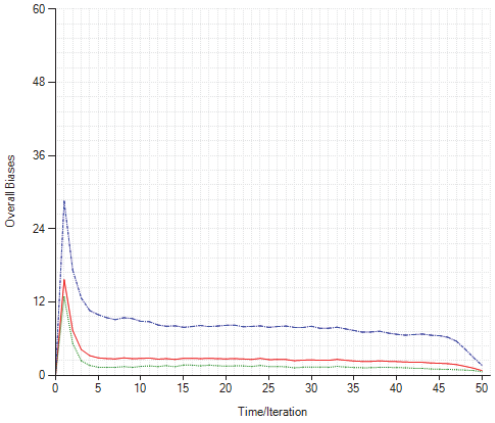
(a) Initial Public Cognition Distribution



(b) Public Attitude Evolution



(c) Evolution of Information Distortion



(d) Evolution of Cognitive Biases

Figure 5.23: The Impact of External Influencing Campaigns

they enter public's eyes from the 6th iteration of computing, and walk aside the public to the end.

Other parameters are set in a regular way to the discussion in previous sections: $\alpha = 0.5$; $\gamma = 1.2$; $\lambda = 0.2$.

The computing outcomes are shown in Figure 5.23.

As we can infer from the panels, prior to the injection of external persuading campaigns, the public's attitudes are quickly converge to a point below the initial level. However, being exposed to the campaigns, the public's attitudes are changed gradually to the persuading direction, and finally reach a

relatively ideal state, slightly above the neutral point. during the changing, the degree of distortion and biased information processing lightens.

Although there are many issues with the above story and the social computing, compared to the reality, the social computing results does encourage us to model the human cognition in this way.

5.4 Summary

This chapter first re-establishes the mental model of individuals by drawing upon the insights acquired from previous chapters, then it sheds lights on the elements involved in constructing a social model.The individual model and the social model are integrated into a social computing model, which is implemented to simulate the processes of peoples' information processing, and to observe their attitude dynamics as well as the accompanying distortion and biases. The outcomes of social computing are analysed from several folds, which on the one hand confirms the assumptions behind the models, and on the other hand provides meaningful insight for real world judgement scenarios.

The chapter solves the research issues (**I3-I9**) recognised in Section 1.2.2 and Section 1.2.3 concerning the conceptualisation, modelling and testing of the contextual effects of social impact on distortion and biases in individual information processing. It also provides computing evidence for answering issue **I10** raised in 1.2.4 regarding research implications for real-world information processing, judgement and communication scenarios founded by complex social networks.

Chapter 6

Conclusions and Future Work

6.1 Conclusions

This thesis has presented substantial insight of understanding the intra-psychological and contextual mechanisms underpinning individual information processing under social impact and the consequential distortion and biases.

The mass of literature was scrutinised from three major lines. The first line is information cognitive processing and attitude shaping. The second line concerns several correlated concepts including bounded rationality, heuristics, cognitive biases and information distortion. The third line marshals the views associated with social impact. These cross-discipline reviews equipped the current research with a wealth of fundamental knowledge, and prepared theoretical foundation for further investigation.

The nature of several critical attitude-relevant constructs, including attitudes in different dimensions, cognitive dissonance, information distortion and cognitive bias, were conceptualised and clarified in the light of literature. Mathematical measurements for these constructs were also designed, which were revisited by further empirical study at the individual level and social computing at the societal level.

At the individual level, a conceptual framework was elaborated to ex-

plain the causal linkages among the constructs involved in individual information processing, such as argument quality and adequacy, source credibility, elaboration/sense-making, individual prior attitude, perceived message attitude and posterior attitude, as well as cognitive dissonance, distortion and bias. The conceptual model was tested by following a typical empirical approach, from stimuli manipulation, instrumentation, experiment design, data collection, to data analysis and findings discussions.

At the societal level, social computing was introduced to picture the information distortion and cognitive biases in a much wide social context and in a longitudinal way. The mental model of individuals acquired from the empirical study at the individual level was refined by incorporating more moderators such as motivation and ability/knowledge, whose effects were not puzzled out due to empirical settings. Then a social contagion model was devised to mirror a complex and dynamic society. The individual model and the societal model were bridged into a dual-observation model. Variables encompassing society structure and dynamics, agent population, messaging and external persuasion campaign, as well as their transitional functions were delineated in this dual-observation model. Their effects on distortion and biases at the societal level were analysed by a series of social computing experiments.

Particularly, the following findings reached by both the empirical study at the individual level and the social computing at the societal level are of great scholarly significance:

- Factors associated with argument quality, peripheral cues (such as source credibility) substantially govern an individual's elaborating and making sense of an incoming persuasive stimulus, which contributes to the individual's attitude shift towards the stimulus advocacy.

- The state of cognitive dissonance is the major driver of distorted or biased processing of the inconsistent cognitive elements implied in an persuasive stimulus, which then restrains the individual from moving towards the stimulus advocacy.

- Individuals' elaboration of an incoming stimulus for sense-making and their information distortion for consistency function as two accompanying and competing forces for attitude construction (fostering vs. inhibiting), This reflects the complicated nature of human information processing behaviour.
- Cognitive dissonance plays a critical role in the interactions between the two competing forces.
- Sequential exposure to advocacy-consistent stimuli may gradually attenuate an individual's information distortion and cognitive biases.
- Without interacting with others, people keep silence and isolated, maintaining stable attitudes. When people interplay with connected others, their attitude alter.
- When the whole society manifests a skew towards an extreme, the substantial majority stands together in high agreement, and their attitudes soon polarise. Those limited dissenters who feel isolated and severe dissonance with the majority will champion their positions in a strongly distorted way. Furthermore, when a non-polarised majority dominates the minority, the former converts the latter while consolidating their own places. When two matching opposite forces are mixed in a society, the effects of neutralisation or negotiation govern the evolution of attitudes, the overall value of the society may converge to a point.
- The null hypothesis asserted by most social psychologists only holds in the condition where individuals will not distort the social information presented to them. However, in reality where people often distortedly or biasedly process the issue-relevant information, it is a long way (or even no way) to reach the uniformity and convergence, and there are substantial distortion and biases especially for the minority party.
- A highly interconnected and fluid society entails active and frequent exchanges among the reshuffling members, leading to intensive changes

in social states. The more interconnected a society is, the less distortion and biases happen; and when social cognition converges, the distortion and biases therefore disappear, due to the reached agreement.

- A homogeneous society is more likely to reach a uniformity and convergence, whereas a heterogeneous society is more likely to end up with chaos, antagonism, and polarisation. These findings deserves intensive attentions.

- Individuals are often exposed to external influence information sources, such as massive media, lectures, promotions, and other kinds of persuasive campaigns, while exchanging with surrounding people. These campaigns interplay with communicative social information, facilitate or suppress their cognition.

6.2 Implications

These findings have implications for different real-world decision-making and judgement scenarios.

Individual information distortion and cognitive biases under social impact can be significantly observed in the scenario of online information dissemination. In recent years, accompanying with the rapid innovations of Internet-enhanced media, is the substantial reshaping of the way people release, access, communicate, share, evaluate and use information[1]. However, online

[1]Take China as example. According to the Statistical Report on Internet Development in China released by China Internet Network Information Center (CNNIC) in January 2015, by the end of December 2014, there were 649 million Internet users in China, and the coverage of Internet was 47.9%; there were about 557 million mobile users. As a functional element, Socializing is extensively integrating into a variety of Internet applications such as instant messaging, searching, online marketing, online media, etc. The highlights of Internet development in China is transforming from quantity to quality and from coverage to depth. The increasing fusion of Internet and traditional economies is substantially reshaping people's lives. The report is available at: https://www.cnnic.cn/hlwfzyj/hlwxzbg/201502/P020150203551802054676.pdf.

information environments are inherently a double-edged sword by providing people with great information convenience as well as information noises. People listen half, understand quarter, think zero and react double[2]. This to some extent describes the state of affairs of people's bounded rationality in online information environments. An abundance of online media forms such as instant messengers, micro-messages, micro-blogs, social network websites, open comments, and so on, are fashioning the brand-new social gene of online information diffusion. Distortion, biases, noises and disorders in information dissemination has been an open issue in the Internet age. What factors incur the distorted processing and biased interpretation towards the information individuals or groups are exposed to? How does the interplay between individuals who are neighbours in terms of time, space, feelings, ideology or interests intensify this kind of distortion and biases? The current research affords theoretical and empirical implications for resolving these issues. Investigations into these issues are of great significance for relevant departments to eliminate the noises, harness the convenience of new media while avoid the harms, and shape a healthy ecology of information dissemination through devising effective and proactive policies for channel intervening and governing.

Another scenario where individual information distortion and cognitive biases under social impact are striking is financial markets. As described by one of the joint laureates of Nobel Prize in Economic Sciences 2013, Robert Shiller, the rising of market prices greatly catalyses investor enthusiasm, which soon spreads across the market in a way of psychological contagion, with amplified stories that might justify the price up-lifting telling everywhere, drawing into the markets more and more investors harbouring fortune illusions even with their doubts about the real market value (Shiller 2014). This is the essence of speculative bubbles in financial markets (Shiller 2014). Behind this essence is investors' distorted and biased processing of the information of market prices, the role of news, stories and media in amplifying this

[2]This argument comes from Internet, with the accurate source unknown.

distorted and biased effects, as well as the spreading and contagion mechanisms of investor psychology, which are the major concerns of scholars in economics and finance recent years.

Besides, the empirical settings in Chapter 4 and the case study in Section 5.3.7 are essentially designed to resolve the controversy over some social issues with great importance, such as public attitudes towards environmental protection, climate change, transgenic foods, firearms control, anti-smoking and so on.

6.3 Future Work

The current research entertains a complex issue, i.e., the cognitive behaviour of human beings situating in social contexts. This is definitely challenging and entails a long way to go and voluminous efforts are required to make. This thesis work presents a start for further devotions, but constitutes only a little part of the research required. Among a plurality of issues awaiting for further examinations, the following points are most remarkable and urgent:

- A more integrative framework providing more potential to empirically observe and quantitatively measure information distortion and cognitive biases to unify the plurality of perspectives. The current research quantitatively measures the distortion and biases in the process of individual mental elaboration. But this measure could not answer questions such as by what means people make such distortion or biased processing, could there be a vehicle to precisely capture the heuristics individuals follow to reach a fast cognitive end, whether the temporal-spatial order of stimuli will change the way of people's mental processing, and whether some information with high accessibility dominates individual processing of a focal stimulus. These are all interesting issues to be trickily delved into. In response to these issues, at the end of this thesis work, the author is happy to announce that he is now developing a rival framework expounding distortion and biases in information

processing, a framework of information sampling. It is expected to be more comprehensive in theoretical and more effective in empirical observation.

- Social impact models need to more accurately capture the reality, where the natural phenomena provides useful hints, such as people stand aside those who share the common cognitive states with them, and those who are temporally and spatially close to them, and gradually walk far away from those with weak familiarity. People make new friends by extra searching the path of their current connections. The attractive and repulsive laws happen in the physical world also apply in human society. This law should be brought into the research associated with the current topic.

- Group and normative pressure are also important influence upon individuals situating in social contexts. The leader effects or the power of the most influential ones are also an important aspect to explore.

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