BJMB
Brazilian Journal of Motor Behavior

Research Article

Age differences in the use of implicit visual cues in a response time task

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https://doi.org/10.20338/bjmb.v13i2.139

HIGHLIGHTS
- Implicit visual cues reduce response time in children, adolescents and adults.
- Young children benefit less from implicit cues than adolescents and adults.
- Developmental changes occur in the use of precue in a decision-making task.

ABBREVIATIONS

43	43 ms prior to stimulus Appearance
86	86 ms prior to stimulus appearance
129	129 ms prior to stimulus appearance
ANOVAs	analyses of variance
IQR	interquartile range
No	no precue was available
SPSS	Statistical Package for Social Sciences software

PUBLICATION DATA
Received 14 Jun 2019
Accepted 30 Jul 2019
Published 01 Aug 2019

BACKGROUND: Although many activities require a complex interrelationship between the performer and stimuli available in the environment, without explicit perception, many aspects regarding developmental changes in the use of implicit cues remain unknown.
AIM: To investigate the use of implicit visual precueing presented at different time intervals in children, adolescents, and adults.
METHOD: Seventy-two people, male and female, constituted four age groups: 8-, 10-, and 12-year-olds, and adults. Participants performed 32 trials, four-choice-time tasks across four conditions: no precue and a 43 ms centralized dot appearing in the stimulus circle at 43, 86, or 129 ms prior to the stimulus. Response times were obtained for each trial and pooled into each condition.
RESULTS: Response times for 8-year-olds were longer than for 12-year-olds and adults and for 10-year-olds were longer than for adults. Response times were longer in the no precue condition compared to when precues were presented at 86 and 129 ms before the stimulus. Response times were longer when precues were presented at 43 ms compared to 129 ms before the stimulus.
CONCLUSION: Implicit precues reduce response time in children, adolescents, and adults, but young children benefit less from implicit precues than adolescents and adults.

KEYWORDS: visual precues| response time | development | decision-making

INTRODUCTION

Living in an environment with abundant sensory cues requires us to continuously search and couple different available sensory stimuli to efficiently organize our motor responses. This mechanism not only requires one to identify useful cues but also to constantly modify the cues used as the environmental demands change. More interestingly, however, is the fact that much of our perception while interacting with the world around us occurs implicitly: the perceiver uses the information conveyed by the sensory cues but is not able to discriminate and/or verbalize its use. For instance, when walking on a crowded sidewalk we obtain information about all the people around us in order to maintain or change our direction but most of the information on where we direct our eyes and which visual cues we acquire occurs without any specific conscious effort.

This mechanism has been elegantly shown in postural control, where coherent unconscious body sway is induced due to visual manipulation in adults [1, 2], adolescents [3], and young children [4]. In this case, to our surprise, even children as young as 4 can couple and use visual information to produce appropriate body sway but without noticing either the use of visual cues or the consequent motor action performed during upright stance [4].

Another strategy employed to examine the influence of sensory cues to motor responses involves the use of precues. Specifically, precues can be defined as information that precedes the appearance of a stimulus [5]. Several studies using congruent precues (the precue conveys truthful information about the upcoming stimulus) have reported a facilitating effect, leading to faster motor responses [6-8].

The facilitating effect of congruent precues in tasks that require rapid visuo-motor responses has been suggested to occur because precues likely influence the attentional system, working like a spotlight [9]. In contrast, Rosenbaum and Komblum[8] suggested that precues elicit pre-programming of an appropriate response before the appearance of the stimulus; later nominated the rapid chase theory [10].

An important issue regarding the effect of precues on response time is the fact that longer elapsed periods between the onset of a precue and the stimulus elicit faster response times. In this way, several studies have proposed that the precue elicits an immediate pre-activation effect of the correspondent motor response, and when the subsequent stimulus occurs, the motor response (based on the stimulus) is facilitated, and congruent stimulus-precue conditions would speed up motor responses [10]. More interesting, however, is the fact that precues can be used unconsciously in such a way that users are not aware of the precue occurring. This is particularly important in order to understand factors that underpin intuitive decision-making. Vorberg and collaborators [11] used a visual masking paradigm in which large arrows (stimulus) masked small arrows (precue) and showed that although the precue remained largely unconscious to the participants, the implicit congruent precues improved responses. The precueing effect was even amplified when the duration between the onset of the precue, still unconscious, and stimulus increased (up to 100 ms)[11].

Although research concerning how precueing affects motor responses is substantial, much still needs to be uncovered about its use by children and adolescents. Children's ability to use precued information was observed some time ago, employing the reaction time [12] and rapid aiming arm movements [13]. In both cases, children used precues to improve their motor responses. More recently, the effect of different elapsed time between the precue and the stimulus was also observed for 10-year-old children [14], but the time intervals between the cue and stimulus were quite large (200, 600, 1000, and 2000 ms). These large time intervals between the cue and the stimulus certainly provide explicit information to the participants, which may confound the cueing effects.

Despite the scarcity of studies regarding the use of precues in children, there are many questions still to be answered, for instance: Do children use implicit cues to improve response times? If so, when do they reach adult-like performance? As mentioned previously, perception underpins most motor actions performed in daily life, including in sport, leisure activities, traffic, etc. Thus, understanding the use of these implicit cues across different ages might shed more light onto how humans perceive and use sensory information for motor skill performance and acquisition. Therefore, the purpose of this study was to investigate the use of visual precueing information presented at different time intervals in children, adolescents, and adults. Our hypothesis was that children possess the ability to use implicit cues to inform visuo-motor actions, but not to the same extent as adults.

METHODS

Participants

Seventy-two people participated in this study. Participants constituted four age groups, each with 18 participants: 8- (8.1±0.4); 10- (9.9±0.3); and 12-year-olds (12.1±0.4); and adults (20.7±1.2). Children and adolescents were recruited through personal contacts with friends and relatives. Young adults were university students who were invited to visit a laboratory at their University, where data collection occurred. No participants reported any known impairment that could affect or prevent their involvement and performance in the study. Children and adolescents' parents and young adults provided written consent prior to any participation. All the protocols were examined and approved by the Institutional Ethics Committee.

Procedures

In the laboratory or in the classroom, participants were asked to sit comfortably in a regular chair placed near a table. A computer (screen size of 13.2 in) and a customized four-button controller were positioned on the table directly in front of the participants. The controller was placed between the computer and the participant, 8 cm from the computer's edge. Participants were requested to rest their right index finger in a holder-button 3 cm from the middle of the controller and to assume a comfortable position. Their left hand rested either on the table or on their thigh.

While maintaining this position, participants were required to press a button corresponding to a stimulus circle presented on the screen monitor, as accurately and quickly as possible. The stimulus circle comprised a four-circle, choice-reaction-time task, developed specifically for this application (Unity software, Version 5.4.0f3, 2016). Prior to the appearance of the stimulus, a 3-second countdown timer was shown. This was followed by the presentation of four circles, in a horizontal line across the center of the computer screen, each with a diameter of 512 pixels and an edge width of 5 pixels. After the appearance of the four blank circles, one of them (the stimulus circle) turned yellow in color, within a randomized period of 2-4 seconds.

Four stimulus conditions were employed in this study: no precue available (No); a black dot appeared, for a total duration of 43 ms, in the center of the stimulus circle, 43 ms prior to appearance of the stimulus (43); 86 ms prior to appearance of the stimulus (86); and 129 ms prior to appearance of the stimulus (129). The appearance of the stimulus for 43 ms was employed because precue durations below 100 ms are ideal to be used as unconscious precues[11] and a 43 ms precue has been identified as appropriate during cognitive responses[15]. Eight trials of each precue condition were performed, in a randomized order and presented subsequently, resulting in a total of 32 trials per participant.

Participants were blinded regarding the appearance of the precueing black dot before the stimulus. Prior to the experimental trials, 5 no-precue trials were performed for familiarization until the participant understood and felt comfortable performing the task. As the participant performed the trials, information regarding the response correctness and the response time were recorded by the custom software and saved onto a spreadsheet. Response correctness was classified as "correct/wrong", based on whether the controller button corresponding/non-corresponding to the stimulus circle was pressed. Response time, given in seconds, was measured as the elapsed time between the appearance of the stimulus circle (circle turned yellow) on the computer screen and the instant that the button was pressed. After completing all the trials, participants were asked whether they discriminated any change and/or differences regarding the stimulus appearance. If the answer was positive, the participant was asked to describe the change and/or difference perceived.

Data Reduction

Participant responses were analyzed using a custom routine written in Matlab (MathWorks, Inc.). This routine loaded the response file and, initially, the response correctness was considered. Responses that did not correspond to the stimulus circle were not considered for further analysis. Furthermore, trials in which the response times were too short and/or too long were also excluded from further analysis, employing an outlier-labeling rule. This rule identified outliers when response time was outside the value associated with the values derived from multiplying each participant's interquartile range (IQR) by 1.5, from which values below/above the 25^{th} and 75^{th} percentiles ± 1.5*IQR were discarded (Hoaglin & Iglewicz, 1987).

Following the response time screening, response times were grouped according to each of the four conditions and the respective means were obtained for each participant. Finally, response times for the implicit precue conditions were transformed into z-scores, using the mean and standard deviation of the respective participant in the NO precue condition. This procedure was employed to minimize the between-participant effect, while still preserving the within-participant condition effect.

Statistical Analysis

Two repeated measures analyses of variance (ANOVAs) were used, with age group (8-; 10-; and 12-year-olds; and adults) as the between-subjects factor and the precue condition as the within-subjects factor. For the first ANOVA, the precue condition had four levels (NO, 43, 86, and 129) and the dependent variable was the response time. For the second ANOVA, the precue condition had three levels (43, 86, and 129) and the dependent variable was the response time z-score for the precue conditions. When appropriate, tests of within-participant contrasts were employed. All procedures were performed using the Statistical Package for Social Sciences software (SPSS) and an alpha level of 0.05 was adopted.

RESULTS

Table 1 depicts the observed errors across the experimental conditions and precue discrimination. Although no statistical comparison was made, there is no indication of any dramatic difference between the age groups for either errors or precue discrimination.

Table 1 - Number of errors across the four conditions of no precue (Dot_no) and with precue 43 ms (Dot_43), 86 ms (Dot_86), and 129 ms (Dot_129) prior to the stimulus and the number of participants that reported precue discrimination at the end of the trials.

	Errors					Precue Discrimination
	Dot_no	Dot_43	Dot_86	Dot_129	**Total**	
8-year-olds	3	1	1	0	5	2
10-year-olds	2	1	2	1	6	7
12-year-olds	1	2	0	1	4	4
Adults	0	0	0	2	2	8

Figure 1 depicts mean and standard deviation of the response time for all four groups and conditions. ANOVA revealed group, $F_{(1,68)}=29.40$, $p<0.001$), and precue condition, $F_{(3,204)}=40.17$, $p<0.001$), but no group by precue condition interaction effect, $F_{(9,204)}=0.96$, $p>0.05$). Post hoc tests indicated that response times for the 8-year-olds were longer than response times for the 12-year-olds and adults. Response times for the 10-year-olds were longer than for the adults. For condition, post hoc tests showed that response times decreased linearly as the precue occurred at a longer time before the stimulus appearance.

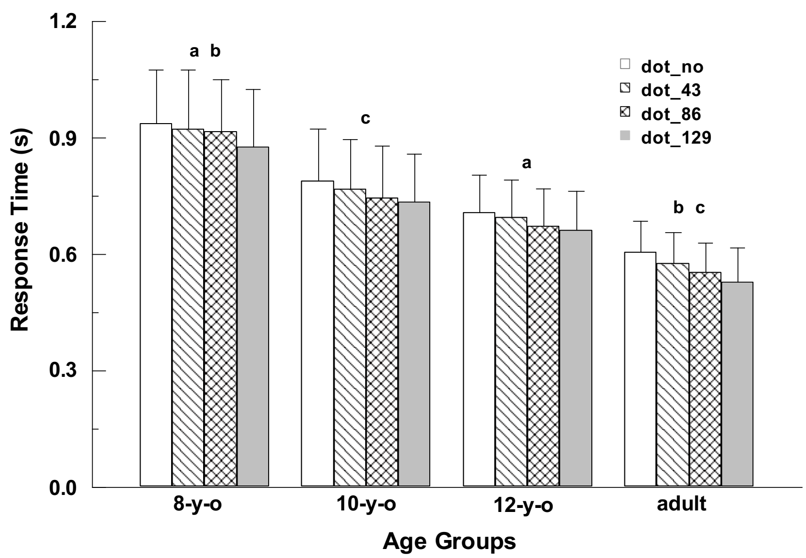

Figure 1. Means and standard deviations of response time (in seconds) for the four age groups (8-, 10-, and 12-year-olds, and adults) in all four precue conditions. Note: Same letters indicate statistically significant difference between age groups.

Figure 2 depicts mean and standard deviation of the z-score for all four groups in the three conditions that the precue occurred. ANOVA revealed group, $F_{(1,68)}=5.43$, $p<0.005$), and precue condition, $F_{(2,136)}=31.17$, $p<0.001$, but no group and precue condition interaction effect, $F_{(6,136)}=1.40$, $p>0.05$. Z-score values were higher for the adults than for the 8-; 10-; and 12-year-olds. Post hoc tests showed that the z-score negatively increased as the precue occurred a longer time before the stimulus appearance.

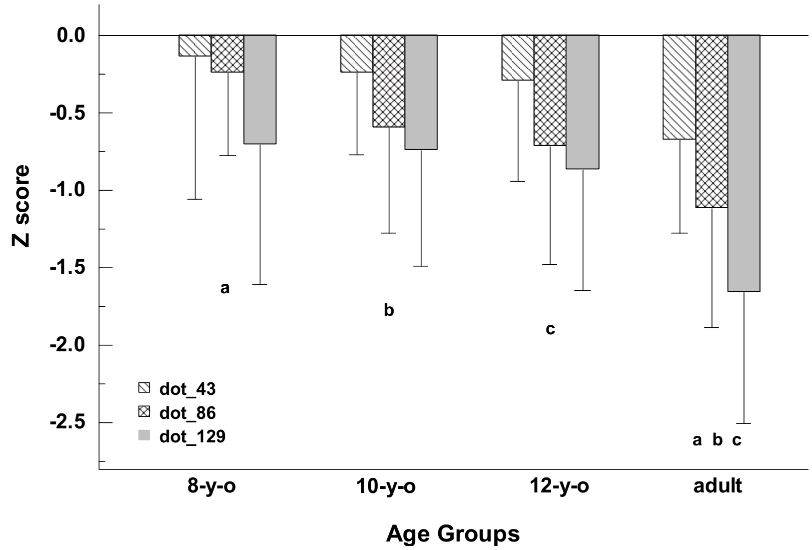

Figure 2. Means and standard deviations of z score for the four age groups (8-, 10-, and 12-year-olds, and adults) in all four precue conditions. Note: Same letters indicate statistically significant difference between age groups.

DISCUSSION

This study examined the use of visual precue information presented at different precue-stimulus intervals in children, adolescents, and adults. Our hypothesis was that children would use implicit precues in the response-time task but would not reach an adult-like level. Our results clearly showed that children reduce the elapsed time in decision-making when an implicit cue is available. However, even when the precue was available, children (8-year-olds) but not adolescents (12-year-olds) required a longer time to make the decisions compared to adults.

The use of precues by children, adolescents and adults is remarkable, with children and adolescents demonstrating the same rate of precue discrimination and errors and reduced response time when the precue is made available. The use of precues by children had already been observed e.g., [12, 13], although response time in young children is longer than that observed for adolescents and adults. Our results showed that response time of 8- and 10-year-olds was longer than the observed response time for adults and that 8-year-old children's response times were also longer than those observed for the 12-year-olds. Longer response time for young children had been previously observed [12, 13] and, therefore, our results confirmed the previous findings.

More interestingly, however, was the observation that participants of all age groups produced reduced response times when the implicit precue was available. This result is new and indicates that even young children are capable of taking advantage of implicit information to improve decision-making. Moreover, our results also showed that with the occurrence of earlier precues considering the stimulus, response time is shortened. This observation indicates that the use of implicit information, due to the precue, requires subliminal central processing and when the cue occurs earlier, the performer can process the information earlier and speed up the response. From the findings of this study, it appears this mechanism is already employed by children as young as 8-years-old.

Regarding the developmental use of implicit information, our results clearly show that although able to take advantage of implicit cues, children and even adolescents are still not as efficient as adults. The z-score values interestingly indicated that even 12-year-olds do not reach an adult-like reduction in the response time when using precues. This novel knowledge might be related to the sensory-motor reweighting results observed in other conditions and employing other paradigms. For instance, the influence of visual manipulation in body sway is also attenuated in young children [4], but still does not reach adult-like values. Although an adult level of sensory-motor reweighting has been observed in adolescents [3, 4], other studies have suggested that in more complex conditions this mechanism seems to mature at older ages [16, 17].

The possible relation among implicit mechanisms such as sensory-motor reweighting and precueing use, among others, indicates that most likely the central nervous system tries to minimize the attentional demands for such basic functional mechanisms. In doing so, it frees an important amount of central processing that can be directed to other decision-making processes and situations which involve attention and knowledge to be judged and explicitly decided. This mechanism is quite clever, allowing people to deal with daily living situations where the perceptual information they need to attend to is abundant. However, despite being in place in the first years of life, as suggested [3, 4], these underlying mechanisms are further fine-tuned into adulthood.

The current study presents a few limitations. Despite showing age-related change in precueing use, it is important to observe when the use of precueing first appears in life. Thus, it is still necessary to examine at which age cue use is first observed. The task employed in this study might be considered simple. Thus, it would be interesting to observe if the use of implicit cues also occurs in more complex tasks, for example, congruent and incongruent stimulus-response conditions. Finally, it would be interesting to compare the results from this choice reaction time paradigm with other more natural tasks in children. Definitely, these limitations will be addressed in future studies and might uncover import knowledge related to the developmental landscape of implicit cues throughout infancy and adolescence.

CONCLUSION

In general, the results suggest that implicit visual precues are used to reduce the time required for visuo-motor responses in children as young as 8-years-old, as well as adolescents and adults. However, young children demonstrated less benefits from the visual precues than the older groups, showing a lesser reduction in the time required to respond to a stimulus.

REFERENCES

1. Freitas Junior PB and Barela JA: Postural control as a function of self- and object-motion perception. Neuroscience letters 2004; 369: 64-68.
2. Barela JA, Weigelt M, Polastri PF, et al.: Explicit and implicit knowledge of environment states induce adaptation in postural control. Neuroscience letters 2014; 566: 6-10.
3. Godoi D and Barela JA: Body sway and sensory motor coupling adaptation in children: effects of distance manipulation. Developmental psychobiology 2008; 50: 77-87.

4. Rinaldi NM, Polastri PF and Barela JA: Age-related changes in postural control sensory reweighting. Neuroscience letters 2009; 467: 225-229.
5. Bugg JM and Smallwood A: The next trial will be conflicting! Effects of explicit congruency pre-cues on cognitive control. Psychological research 2016; 80: 16-33.
6. Welsh TN and Elliot D: Effects of response priming and inhibition on movement planning and execution. Journal of motor behavior 2004; 36: 200-211.
7. Hutchison KA, Bugg JM, Lim YB, et al.: Congruency precues moderate item-specific proportion congruency effects. Attention, perception & psychophysics 2016; 78: 1087-1103.
8. Rosenbaum DA and Kornblum S: A priming method for investigating the selection of motor responses. ACTA PSYCHOL 1982; 51: 223-243.
9. Posner MI, Snyder CR and Davidson BJ: Attention and the detection of signals. Journal of experimental psychology 1980; 109: 160-174.
10. Schmidt T, Niehaus S and Nagel A: Primes and targets in rapid chases: tracing sequential waves of motor activation. Behavioral neuroscience 2006; 120: 1005-1016.
11. Vorberg D, Mattler U, Heinecke A, et al.: Different time courses for visual perception and action priming. Proceedings of the National Academy of Sciences of the United States of America 2003; 100: 6275-6280.
12. Clark JE and Moore JW: Yiung children's ability to use precued information to select and maintain a response. PERCEPT MOTOR SKILL 1981; 52: 655-658.
13. Yan JH, Thomas JR, Stelmach GE, et al.: Developmental features of rapid aiming arm movements across the lifespan. Journal of motor behavior 2000; 32: 121-140.
14. Adam JJ, Ament B and Hurks P: Response preparation with anticues in children and adults. J COGN PSYCHOL 2011; 23: 264-271.
15. Dehaene S, Naccache L, LeClec'H G, et al.: Imaging unconscious semantic priming. 1998; 395: 597-600.
16. Peterson ML, Christou E and Rosengren KS: Children achieve adult-like sensory integration during stance at 12-years-old. Gait & posture 2006; 23: 455-463.
17. Polastri PF and Barela JA: Adaptive visual re-weighting in children's postural control. PloS one 2013; 8: e82215.

Citation: Barela JA, Rocha AA,Novak AR,Fransen J, Figueiredo GA.Age differences in the use of implicit visual cues in a response time task. BJMB. 2019: 13(2): 86-93.
Editor: Dr Fabio Augusto Barbieri - São Paulo State University (UNESP), Bauru, SP, Brazil; Dr Natalia Madalena Rinaldi - Federal University of Espírito Santo (UFES), Vitória, ES, Brazil.

Funding: There was no funding for this study.
Competing interests: The authors have declared that no competing interests exist.
DOI: 10.20338/bjmb.v13i2.139