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The Effectiveness of Visual and Auditory Elements of a Compound Stimulus in Controlling Behavior in the Domestic Dog (*Canis familiaris*)

Selina Gibsone [a]; E. Anne McBride [a]; Edward S. Redhead [a]; Kristie E. Cameron [b]; Lewis A. Bizo [c],

Author's Institution:

A University of Southampton

B Unitec, Institute of Technology, Auckland

C University of Technology Sydney

Corresponding Author: Dr Edward S. Redhead

Email: E.Redhead@soton.ac.uk

Address: School of Psychology

University of Southampton

University Road

SO17 1BJ

UK

Research Highlights

Hand signals and voice signals are commonly used by owners and handlers to control the behavior of both companion and working dogs. However, the common practice of training animals with compound stimuli may introduce sources of error and later failure to respond correctly to cues.

Dogs performed a target behavior in response to a two-element compound stimulus composed of a hand (visual) signal and a voice (auditory) signal.

When tested with individual elements of the compound stimulus there was a significant decrease in correct responses compared to the trained compound stimulus.

The majority of dogs responded at higher rates to auditory-only cues than to visual-only cues.

Subsequent poor responding to the elements of a stimulus has implications for the success of training assistance/service dogs when a compound stimulus has been used initially.

Abstract

This study measured the responses of dogs to signals delivered via hand and voice signals. The study sought to determine whether dogs would display differential stimulus control when switching from a compound stimulus (auditory-visual) cue to presentation of only one of its elements. Twelve dogs performed a target behavior in response to a two-element compound stimulus composed of a hand (visual modality) signal and a voice (auditory modality) signal. The mean percent correct responses to the visual element (M = 56.5, SD = 20.74) and the auditory element (M = 67.5, SD = 21.57) were both significantly lower than the 85% correct for the compound stimulus, $p < 0.017$. There was also evidence of a preference for one of the elements of the compound stimulus. The mean percent correct for the more favoured element (M = 77.25, SD = 12.53) was significantly higher than for the less favoured element (M = 46.75, SD = 17.2), $p < 0.001$. The identity of the favoured element was not consistent across the animals with 75% preferring the auditory element and 25% the visual element. This study contributes to an understanding of factors related to the stimulus control of learned behaviors. The differential control of behavior by alternative cues has implications for the training of assistance or service and other working animals with multiple cues. The results would strongly suggest that training with a compound stimulus is not appropriate if only elements of the compound stimulus are to be subsequently used.

Keywords: Compound stimuli, stimulus control, discrimination, dog training, dog

The Effectiveness of Visual and Auditory Elements of a Compound Stimulus in Controlling Behavior in the Domestic Dog (*Canis familiaris*)

Hand signals and voice signals are commonly used together to control the behavior of both companion and working dogs (*Canis lupus familiaris*; Erlandson, 1994; McConnell, 2002; Scrimgeour, 2002). For example, Hearing Dogs for Deaf People is an UK-based organization that trains dogs to assist people with severe hearing impairment. The dogs are trained to respond to both hand and voice signals. In training, these signals are delivered simultaneously as elements of a compound stimulus, where each element predicts a common outcome (Fetterman, 1996). When dogs are assigned to a potential recipient, they are further trained to respond solely to the element of the cue that is most appropriate to that recipient's physical abilities. Many recipients are profoundly deaf and have difficulties using speech and thus find hand signals easier to use (Guest, 2003). In a survey of fifty-one recipients who applied for a hearing dog between 1991 and 1993, nearly 8% indicated little or no speech, 31.4% reported some speech and 60.8% indicated normal speech. Conversely, some recipients reported voice cues were easier to use due to mobility or balance problems (Guest, 2003). Training animals with compound stimuli composed of two elements may introduce sources of error and later failure to respond correctly, especially when presented with only one element of the compound stimulus. This may be of particular importance when training working animals, such as those used as assistance dogs for persons with disabilities.

Developing a good understanding of those factors that promote or detract from training is of considerable applied importance. For example, the role of clickers used in training dogs and horses (*Equus caballus*) has recently received some attention, with there being no obvious benefit observed when clickers or spoken words were used than when they were not (Williams et al.,2004; Chiandetti et al., 2016).

The development of stimulus control over behavior has a long tradition in the study of animal learning, which translates well to applied animal behavior (Moser et al.,2019). A seminal contribution to our understanding of stimulus control by Reynolds (1961) reported differential stimulus control of responses by two pigeons (*Columbidae spp.*) to individual elements of a compound stimulus to which they had been trained to respond. The compound stimulus was a white triangle on a red disk. When tested with the individual elements, one pigeon responded almost exclusively to the white triangle and the other to the red disk, despite the pigeons receiving the same training. A replication by Blackmore et al. (2016) had two cows (*Bos taurus*) learn to discriminate a red cross from a yellow triangle. In subsequent testing, they found that color but not shape controlled behavior. These and other studies demonstrate that, though the trained stimulus includes more than one element, only one of the elements controls the response (Reynolds, 1968; Sutherland and Mackintosh, 1971; Pearce and Bouton, 2001).

One explanation for this phenomena is overshadowing (Reynolds, 1961). Overshadowing occurs when one element of a compound stimulus acquires more control of behavior than the other (Foree and Lolordo, 1973; Spetch, 1995; Fetterman, 1996). The presence of the stronger or more salient element can overshadow the weaker or less salient element, thereby controlling the behavior (Miles and Jenkins, 1973; Mackintosh, 1976). Overshadowing has been demonstrated in a wide variety of species and for a range of behaviors. For example, in dogs, it has been shown to influence their timing of fixed intervals (Macpherson and Roberts, 2017) and the learning of verbal cues for different types of responses (Ramos and Mills, 2019). The salience of an element can be manipulated by increasing its intensity or its probability of predicting reinforcement (Wagner et al, 1968; Miles and Jenkins, 1973).

Which element of a compound stimulus is more salient to an animal may be influenced by species-specific characteristics (Timberlake, 1994). Indeed researchers have shown that the type of stimulus that more readily becomes associated with an outcome can vary across species (Garcia and Koelling, 1966; Wilcoxon et al., 1971), and, particularly important to the current study, across different breeds of dog, (Lipman and Grassi, 1942; Heffner, 1983; Miklósi, 2007; Autier-Derian et al., 2013; Miklósi, and Kubinyi, 2016; Byosiere et al., 2018).

One study investigated the response of dogs to a compound stimulus composed of a light and a tone (Haney and Crowder, 1977). They reported that the visual element overshadowed the auditory element, and came to control the behavior of the dogs more effectively. However, another study found that dogs responded more reliably to the auditory than the visual element of a compound stimulus (Jenkins et al., 1978).

The behavior being trained can also influence which element of a compound stimulus is more salient and comes to control the behavior. For example, Dobrzecka et al. (1966) trained dogs to place their right paw on a feeder on hearing a metronome (auditory cue) positioned in front of them (spatial cue) and to place their left paw on the feeder on hearing a buzzer (auditory cue) positioned behind them (spatial cue). He found that the spatial cue controlled dogs' performance more than the auditory cue. The dogs were almost unable to correctly complete this task when only the auditory cues were available.

However, when the dogs were trained to simply lift their right paw on hearing a metronome positioned behind or not raising the paw on hearing the buzzer behind, the type of sound rather than the spatial position, controlled behavior.

The examples discussed indicate that dogs may be differentially prepared to perform particular behaviors in response to certain stimuli. The inherited characteristics of an animal may affect which elements of a compound stimulus are more salient, depending on the reinforcer. In some settings, the nature of the stimulus being detected may be quite complex such as is the case with odor detection. (Moser et al., 2020).

The current study aimed to determine whether dogs' performance of a specific cued response would decline when switching from a compound stimulus (hand gesture and voice signal) to a presentation of only one of its elements. This is the first time the performance of such cues, prevalent in the training of assistance dogs, have been investigated within a controlled experimental study. It was hypothesized that performance would drop when switching from a compound stimulus to one of its elements due to overshadowing (Reynolds, 1961). The secondary aim was to investigate whether there was a consistent preferred modality of the compound stimulus across the dogs to provide further information as to optimal training technique. We use the word modality throughout the paper to indicate the particular mode in which the signal is given (i.e., in a visual or auditory mode). Therefore, we tested whether the hand gesture (visual modality) or voice signal (auditory modality) produced better responding when presented alone.

In addition, the dogs in the study were from a variety of breeds. Therefore, it may be expected that there would be a variation in responses to stimulus modality based on their breed (Autier-Derian et al., 2013). Such data would provide insight into the optimal stimulus modality to use when training assistance dogs.

Method

Subjects

A total of 16 dogs (seven males, nine females) of various breeds with a mean age of 3.3 years (SD = 2.14) took part in this study. Four dogs did not complete the experiment and their data is not included in the analysis. All dogs were pets owned by dog training staff at Hearing Dogs for Deaf People. No dog was part of a multi-dog household. Previous to start of experiment all dogs had been trained to sit and lay down using the same simultaneous visual and verbal signals, but none had prior experience with training for the experimental behavior of touching a cup. Table 1 provides the demographic details of the dogs that completed the experiment.

<<Insert Table 1 about here>>

The dogs were randomly assigned to one of two groups, Group 1 and Group 2, to control for cue presentation order during training and testing. Stimuli, both the compound stimulus and the individual elements, were presented in pseudo-random order, such that the same cues could not occur more than three times in a row (Please see supplementary materials Appendix A and B).

This research was conducted with the approval of the Programme Ethical Review Body at the University of Southampton.

Apparatus

All training and testing sessions were conducted in a quiet, undisturbed room in the owner's home. The room chosen minimized outside distraction, for example, being away from the road.

The food used to reinforce behavior was Arden Grange Classic Adult (Arden Grange, Albourne, West Sussex, UK) dry complete dog food. One piece of this food weighed 0.5 g and was approximately 1 cm in diameter, and 0.5 cm thick.

Food pellets were delivered through a small opening on one side of the wooden box (20 cm x 20 cm x 20 cm) that enclosed a commercially available operant food dispenser (MED-Associates Inc, ENV-203, Fairfax, VT, USA). When the Experimenter depressed a plastic treadle with her foot, a single food pellet was released.

The cup, which the dog had to learn to touch with its nose, was a black cardboard cup (Hieght 15 cm, Width 9 cm) upside down and stapled to a card (Length 12 cm x Width 12 cm) placed on the floor. Each dog used the same cup for all its training and test sessions. A different cup was used for each dog. For all sessions, the duration of the trials was recorded using a stopwatch, responses were recorded on a clip board around the experimenter’s neck and only the experimenter (SG) and the dog were present in the room. The experimenter was an experienced pet and Hearing Dog trainer.

The experimenter wore a baseball cap low over her face to reduce influence of facial expressions and eye gaze over the behavior of the dog. The experimenter presented cues to the dog from a fixed position relative to the apparatus and the dog, as shown in Figure 1 and recorded the duration of the trials using a stopwatch and recorded the dogs responses on a clipboard around her neck.

<<Insert Figure 1 about here>>

Procedure

Prior to the study all dogs had been previously trained by their owner to respond to two compound stimuli; 'SIT' and 'DOWN'. The owners were all staff at hearing dogs for deaf people and followed the same training methodology as the organisation.

SIT – 'sit' spoken word + hand signal 1.

DOWN – 'down' spoken word + hand signal 2.

See Figure 2 for detailed description of hand signals used for SIT and DOWN.

<<Insert Figure 2 about here>>

Before commencing the first session, the Experimenter verified the dog's competency at performing responses to the SIT and Down compound stimuli by requiring the dog to correctly respond to each compound stimulus on 10 occasions. The responses were not reinforced.

Training

The experiment was conducted over a period of nine days for each dog. Each day consisted of four short training sessions lasting no longer than 30 minutes with a 10 minute break between sessions. Dogs were deprived of food for at least 6 hours before each session.

Magazine Training: The dog was allowed to enter and freely explore the room by the experimenter. When the dog was within 30 cm of the food dispenser the experimenter pressed the treadle to release one pellet of food. The next food pellet would not be released until the pellet had been eaten and the dog had turned away from the food dispenser. Magazine training ended when the dogs immediately approached food dispenser on hearing food pellet released on 20 consecutive trials.

Shaping cup touching behaviour: The dogs were trained to touch the cup using a method of shaping by successive approximations with the following four response criteria: Look at cup; Approach cup; Sniff cup; Place paw on cup.

At the start of shaping, the dog was again allowed to freely explore the room. For the first response criterion the experimenter waited for the dog to look at the cup. When the dog had made a correct response, a single piece of food was delivered to the dog via the food dispenser. When the dog had made 40 reinforced responses the criterion for reinforcement was changed to Approach cup. At each criterion level reinforcement was withheld for the previous response and only given when they had accomplished the current response. Once the dog had performed the response of touching the cup 40 times this stage of training was concluded.

Training response to compound stimulus: At the start of each trial the dog was brought in front of the Experimenter and given the SIT signal. Before the compound stimulus CUP was given, the dog was required to be looking at the experimenter to ensure the dog could both see the hand signal and hear the voice signal. The compound stimulus CUP would then be given to the dog (see Figure 2 for detailed description of hand signal used for CUP). The experimenter spoke all vocal elements in a quiet, neutral and calm voice.

The Experimenter waited for the dog to touch the cup. When it did so, the dog received a single piece of food delivered by the food dispenser. If the dog did not perform the behaviour within 10 s of the compound stimulus being presented the shaping procedure was resumed with reinforcement given for touching the cup without presenting the compound stimulus. After the dog performed the behaviour 40 times during the shaping procedure, training with the compound stimulus was restarted. The stage was completed when the dog had performed the correct response following the CUP compound stimulus on 40 consecutive trials.

Maintenance of Responding by Partial Reinforcement: The Down compound stimulus was added at this stage of training to ensure the dogs had associated the appropriate response with the CUP cue rather than merely repeating a frequently reinforced behaviour.

For each trial, the dog was first required to sit in front of the Experimenter with the SIT signal. The trials consisted of an equal number of DOWN and CUP compound stimuli in the order prescribed for Group 1 and 2 (see supplementary materials Appendices A). All correct responses resulted in food being delivered via the food dispenser. If the dog made an incorrect response, it would receive a correction trial, where the cue was repeated. The same signal was given on each correction trial until the dog responded correctly. Once the dog maintained 90% accuracy over 20 consecutive trials, the rate of reinforcement was decreased to 70%. Correct responses on 14 of the 20 trials were followed by a pellet delivery, the order of reinforced and non-reinforced trials is shown in supplementary materials. Reinforcement stayed at this level until the dog maintained 90% accuracy over 20 consecutive trials. If the accuracy dropped below 90%, the rate of reinforcement was restored to the previous level until performance recovered to 90% over 20 consecutive trials. Once this criteria was met, reinforcement rate was reduced to 50% and the same procedure followed. Finally, the reinforcement rate was reduced to 35% until the dog maintained 90% accuracy over 20 consecutive trials.

Experimental Testing

Before each trial, the dog was first required to sit in front of the Experimenter. The control stimuli were the DOWN and CUP compound stimuli. The test stimuli were the elements "*cup-Verbal*" and "*cup-Hand*".

The experiment was run in sets of 60 trials that comprised 40 control trials (20 each of DOWN and CUP compound stimuli) on which 50% of correct responses were reinforced. Interspersed were the 20 test trials (10 each of element stimuli *cup-H* and *cup-V*). A dog’s response on the test trials was never reinforced. The order of test trials were arranged such that elements of the same modality did not occur immediately after each other. The order of trials and reinforcement can be seen in supplementary materials Appendix B. Each dog completed ten experimental sets, thus there were 400 control and 200 test trials.

The experimenter recorded the time taken to complete each experimental set and the correct response to each trial. A response to the test trials was considered incorrect if a dog did not carry out the required response. If the error was in a control trial, the dog experienced a correction trial where the stimulus was repeated. If the dog then responded correctly, the testing continued. If the dog’s performance on the combined control trials fell below 85% over a 20 trial block, the testing was stopped. For example, within a block of twenty trials, seven were test trials and thirteen were control trials, so the dogs had to respond correctly to eleven of the thirteen control trials to continue. If the dog made more than two errors to the control trials, the dog was then presented with twenty compound stimulus training trials reinforced at 100% to bring performance back up. Testing would then resume at the point it had been halted. The study was ended once all of the 10 sets of trials had been successfully completed.

Results

Training Shaping, Compound Stimulus and Partial reinforcement

The mean time to successfully complete shaping for each of the dogs can be seen in Table 2.

<<Insert Table 2 about here>>

An independent samples t-test showed that the difference between the dogs in Groups 1 and 2 was not significant, t (10) = -1.1, p = 0.295. The mean time to successfully complete initial training with the CUP compound stimulus for each of the dogs can be seen in Table 2. An independent samples t-test showed that the difference between the dogs in Groups 1 and 2 was not significant, t (10) = -1.4, p = 0.180. A further independent samples t-test showed that the difference between the dogs that subsequently favoured the visual element of the compound stimulus to those that favoured the hand element was not significant, t (10) = 0.52, p = 0.612. The mean time to successfully complete training with the partially reinforced control compound stimuli for each of the dogs can be seen in Table 2. An independent samples t-test showed that the difference between the dogs in Groups 1 and 2 was not significant, t (10) = -0.08, p = 0.993. A further independent samples t-test showed that the difference between the dogs that subsequently favoured the visual element of the compound stimulus to those that favoured the hand element was also not significant, t (10) = -0.76, p = 0.463.

Test stage

The mean time to successfully complete the test stage for each of the dogs can be seen in Table 3. An independent samples t-test showed that the difference between the dogs in Groups 1 (*M* = 4012.00 s, *SD* = 329.66) and 2 (*M* = 3672.00 s, *SD* = 825.76) was not significant, t (10) = 0.93 , p = 0.372.

The percentage correct response to control compound stimuli and test elements stimuli for each dog during the ten sets of training trials can be seen in Table 3.

<<Insert Table 3 about here>>

The mean percentage correct responses for all dogs for the CUP compound stimulus and the two test stimuli (*cup-H* and *cup-V*) across the 10 trial sets can be seen in Fig 3.

<<Insert Figure 3 about here>>

To confirm this impression a mixed-design ANOVA of group x stimulus x trial set was performed with the percentage correct responses as the dependent variable. There was no significant difference between the groups, $F < 1$ nor were there any significant interactions involving the groups, (Group x Stimulus, $F < 1$; Group x Trial Set, F (9, 90) = 1.33, p = 0.273; Group x Stimulus x Trial Set, $F < 1$). The effect of trial set was also not significant, F (9, 90) = 1.95, p = 0.054, nor was the interaction between trial set and stimulus, F (9, 90) = 1.15, p = 0.307. The difference between stimuli was significant, F (2, 20) = 9.17, p = 0.001. To examine the difference between the stimuli further three Post hoc paired t-tests were performed comparing the mean percentage responding to the Cup Compound stimulus collapsed across trial sets to both the test element stimuli and comparing the test stimuli to each other. Using the Bonferoni correction, percentage correct responding to the Cup Compound Stimulus (*M* = 89.79, *SD* = 3.52) was found to be significantly higher than to the *cup-H* stimulus (*M* = 56.33, *SD* =20.87), t (11) = -5.58,

$p < 0.00.1$ and significantly higher than to the *cup-V* stimulus (($M = 65.99$, $SD = 20.94$), t (11) = -3.89, $p = 0.03$. The difference between the test element stimuli was not significant, t (11) = 0.93, $p = 0.366$. Therefore, the dogs' performance, when presented with the CUP compound stimulus was significantly superior to their performance to both the elements when presented alone.

Even though there was no consistent difference between the hand and voice elements there were clear individual differences for all dogs. Table 4 shows the percentage correct responses to *cup-H* and *cup-V* for each dog. Eight of the twelve dogs responded more accurately to the voice signal, and four more accurately to the hand signal. For some, these differences were substantial, such as for Fizz, Jinx, Scout, and Pippa.

<<Insert Table 4 about here>>

Two individual dogs, Fizz and Scout, showed extreme preferences for one modality. Fizz performed 97% correct responses for the voice signal presented alone and 25% correct responses to the hand signal. Scout performed 88% correct responses for the hand signal alone, and 25% correct for the voice signal alone.

The mean performance suggests the dogs did not show superior performance to a particular stimulus modality (hand or vocal). However, as each dog appeared to favor one modality over the other it is important to compare the performance of the favored element stimulus to the Cup compound stimulus to see if there is still a drop in performance to this favoured stimulus. An independent samples t-test with time to complete the test stage as the dependent variable showed that the difference between the dogs that favored the voice signal (*M* = 3961.25 s, *SD* = 386.87) and those that favoured the hand signal (*M* = 3604.75 s, *SD* = 985.12) was not significant, t (10) = 0.92 , $p = 0.377$.

The mean percentage correct responses for all dogs for the CUP compound stimulus and the Dominant and Weak modality stimuli across the 10 trial sets can be seen in Fig 4.

<<Insert Figure 4 about here>>

The Dominant modality elicits a higher percentage correct responses than the weaker modality stimulus but, the Dominant stimulus is still lower than the CUP Compound stimulus across all Trial sets including the first. A mixed-design ANOVA of modality preference (voice and hand signal) x stimulus (Dominant, Weak and Compound stimulus) x trial set was performed to investigate the difference between the more and less favored modality and their relationship to the CUP compound control stimulus. The percentage correct responses to the three stimuli was the dependent variable. There was no significant effect of modal preference, $F < 1$ nor were there any significant interactions involving the modal preference, (Modal Preference x Stimulus; Modal Preference x Trial Set; Modal Preference x Stimulus x Trial Set, Fs < 1). The effect of trial set was also not significant, F (9, 90) = 1.94, $p = 0.056$, nor was there a significant interaction between trial set and stimulus, F (18, 180) = 1.59, $p < 0.300$. The difference between stimuli was significant, F (2, 20) = 39.20, $p < 0.001$. To examine the difference between the stimuli further 3 Post hoc paired t-tests were performed comparing the mean percentage responding to the Cup Compound stimulus collapsed across session to the Dominant and Weak element stimuli and comparing these test stimuli to each other. Using the Bonferoni correction, percentage correct responding to the Cup Compound

Stimulus (M = 89.79, SD = 3.52) was found to be significantly higher than to the Dominant stimulus (M = 76.42, SD =11.48), t (11) = -4.55, p = 0.001 and significantly higher than to the Weak stimulus (M = 45.91, SD = 16.91), t (11) = -8.49, $p < 0.001$. The difference between the test element stimuli was also significant, t (11) = 5.68, $p < 0.001$. Therefore, the dogs' performance, when presented with the CUP compound stimulus was significantly superior to their performance to both the Dominant and Weak elements when presented alone and responses to the favored test stimulus was greater than to the less favoured element.

There were not enough animals in each breed group for a statistical analysis of breed differences. The two terriers both showed a preference to hand signals. The two collie types and the two Labradors showed a preference for voice signals. Four spaniels showed a preference for voice signals and two a preference for hand signals (See Table 4).

Association between training and responding to test stimuli

To test if there was any relationship between the length of time it took to train an animal to criterion during the various stages of training and the observed outcomes of the test results a series of Pearson r correlations was performed. Time to train each dog during each stage was correlated with the dog's performance on each trial set for each test stimulus during the test stage. There was a significant negative correlation between the time to initially train the dogs to the Cup compound stimulus and the outcome of *cup-H* trials in the final three trial sets. For trial set 8, r (12) = -0.593, $p < 0.042$, for trial set 9, r (12) = -0.612, $p < 0.034$, and for trial set 10, r (12) = -0.586, $p < 0.045$. The longer it took to train the dogs to touch the cup following the CUP compound stimulus, the weaker the responding to the Hand element stimulus in the final trial sets of testing. There were no other significant correlations between time to train and responding to test stimuli.

Discussion

The present study investigated the effects of training dogs to hand and voice signals as a compound stimulus and testing with the individual elements. The rationale for the study was its application to a real-world situation, specifically the initial training of assistance dogs to a compound stimulus with subsequent use of the element most appropriate to that recipient's physical abilities. Compared to the initially trained compound stimulus, there was a significant reduction in correct responding to the visual and auditory elements presented individually. It is important to note that this lower level of correct responding is seen from the very first trial set. Unlike the Compound Stimulus where the animals received partial reinforcement and correction trials to maintain the level of responding, the responses to the Test stimuli were never reinforced. Any lower percentage of correct responding towards the end of the study could be attributed to this absence of food following a correct response. However, as seen in Fig 3, the level of responding is fairly constant across trial sets, and there was no significant effect of trial set or trial set x trial type interaction in the analysis of this data. The lower level of percentage correct responding can only be due to the perceived difference between the trained Cup Compound stimulus and the test stimuli. This decrease in correct responding to the elements of the compound stimulus aligns with evidence from other studies and, as described in the introduction, can be predicted by overshadowing of one element of the stimulus compound by the more salient element (Wolf, 1963; Miller and Ackley, 1970; Kehoe et al., 1994).

It could be possible that dogs were responding to other non-verbal cues that we have not completely controlled for in the study. Measures were taken to limit the gaze cues provided by the eyes of the experimenter as to the correct response by requiring the experimenter to wear a baseball cap. However, it has to be acknowledged that this would not completely rule out use of gaze cues by the dogs in addition to the compound stimulus and individual elements of the compound stimulus. In a future experiment it might be useful to use a cue which completely obscured such cues or an experimenter that is blinded to the correct responses.

Numerically more dogs displayed preferential responding to the voice signals than to the hand gestures suggesting that the auditory element of the compound stimulus was more salient than the visual element. This finding contrasts with those of Haney and Crowder (1977) who found that a visual stimulus (a light) exerted greater stimulus control than an auditory stimulus (a tone) for dogs in a modified operant chamber. The different findings in the current study may be due to the different presentation of stimuli in isolation, compared to via a human. The current experiment was explicitly designed to be more applicable to the real-world practice of dog training and thus be more ecologically valid. It may be interesting to compare responses of dogs to human-delivered hand signals and voice signals with arbitrary mechanically-delivered stimuli such as lights and tones.

The dogs used in the present study were not hearing assistance dogs. However, it may be that the observed preference for the auditory over visual element is more pronounced in hearing assistance dogs. The role of a hearing dog is to respond to a variety of household sounds, so dogs that are more responsive to auditory stimuli are more likely to be selected. Therefore, these dogs may be more likely to respond to any auditory stimuli, including voice, rather than visual stimuli. When the training uses compound stimuli, this inherent favoring of auditory stimuli will make it more difficult to train these dogs to respond reliably to just hand signals as necessary for particular recipients. It would therefore be valuable to repeat the current study with working assistance dogs to test this hypothesis.

An alternative explanation for the preference for one element of the compound stimulus over another may be due to previous exposure to that element. This is termed blocking (Reynolds, 1968) and is a common phenomenon in the animal learning literature (Kamin, 1969). Blocking occurs when one element of a compound stimulus has previously signalled an outcome. This will lead the animal to only attend to this element of the compound stimulus during training with the compound stimulus and prevent learning about the other (Ono and Iwabuchi, 1997). A future study where one element of the compound stimulus is explicitly pre-trained would provide useful information regarding the impact of blocking on subsequent training with a compound stimulus and subsequent level of responding to the individual elements.

It has to be acknowledged that individual training histories of the dogs, including pre-training to the SIT and DOWN signals could have resulted in the individual differences seen in the performance to the two elements of the compound stimuli. For example, Fizz showed the largest preference for the voice signal over the hand signal and this may reflect differences in previous training. Fizz took part in agility training where the dog responds to the handler from a distance meaning the dog cannot always see the handler. This may have lead Fizz to become more attentive to voice signals than hand signals. It would have been informative if the elements of the SIT and Down had also been separately tested to assess the consistency of the modality preference for each dog.

While individual histories may have influenced to which modalities they attended, preferences might also reflect an inherited tendency. Research has shown that breeds may differ in their problem-solving ability, emotional reactivity, and motivational characteristics (Scott and Fuller, 1965). The small sample in the present study precludes any definitive conclusion, but it would be valuable to investigate the possibility of breed-specific preferences for responding to different modalities of stimuli.

Regardless of whether preferences develop through earlier training or inherent tendencies of the breed, the present study demonstrates that training a compound stimulus may not be the most effective means of training if only one element of the compound stimulus is to be subsequently used. It would be helpful if further research could investigate the ease with which the element stimuli could be subsequently trained. If previous training history is key and blocking (Kamin, 1968) is responsible for the drop in responding it may be that further training might not help. It would be useful to investigate how long the effect of blocking might last or whether it is even possible to train the element for that particular response.

In conclusion, the paper demonstrated that when the elements of a trained compound stimulus were presented individually, there was a decrease in the percentage of correct responses. This is in line with both overshadowing (Reynolds, 1961) and blocking (Kamin, 1969), phenomena commonly seen in animal learning literature. There was also evidence of a preference for one of the elements of the compound stimulus in most dogs, although the favoured modality was not consistent across the animals. The results suggest a need to consider the optimal modality of signal in terms of the client when designing the training. If it is not possible to know particulars of a prospective client at the point of training, the results of the current suggest that further training of the elements of the compound stimulus might be required once the dog is *in situ*. Overall the information gained from the results of this experiment has important implications for the methods used to train dogs if it is subsequently necessary to rely on a single element of the trained compound stimulus. The results further illustrate the importance of applying findings from research in the experimental analysis of behavior to produce the most effective means of animal training.

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