A jump to the left and a step to the right: A test of two accounts of peak shift

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Abstract

“Peak Shift” usually occurs following intradimensional-discrimination training and involves a shift of the peak of the generalization gradient away from the original discriminative stimulus (S+) in a direction away from an S-. Two theoretical accounts of peak shift, the gradient interaction theory (GIT) and adaptation level theory (ALT), were compared. The effects of asymmetric test stimuli and the impact of instructions to participants for them to treat stimuli as members of categories on generalization gradients were investigated. In Experiment 1, the relation between peak shifts obtained when an extended asymmetric set of test stimuli was employed and the occurrence of categorization of the stimuli involved was investigated in four separate conditions. Two involved temporal discrimination, one involved line-angle discrimination, and one involved a compound line-angle and temporal cue discrimination. If participants treated the stimuli as belonging to discrete categories, such as hands-on a clock, rather than as being on continuous dimensions then responding to the compound cue was expected to result in attenuation of blocking of a peak shift. However, the peak shift obtained to the three cue types were the same. In Experiment 2, an independent group of participants was given explicit instructions to treat the line angles as if they were the hands of a clock face and this eliminated peak shift. The results from the present experiments support an ALT interpretation, although the peak shifts were significantly smaller in magnitude than predicted by this account.

Keywords Peak Shift · Generalization · Stimulus Control · Intradimensional Discrimination

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Guttman and Kalish (1956) provided one of the first empirical examples of stimulus generalization, and their procedure precipitated a large number of related experiments over subsequent years (for reviews see Ghirlanda and Enquist 2003; Honig and Urcuioli 1981). Guttman and Kalish trained pigeons to peck a stimulus key that was illuminated by monochromatic light of 550 nm—the S+. The pigeons were subsequently allowed to peck the same key that was illuminated with each of 11 wavelengths of light varying from 490 to 610 nm presented in random order on separate trials during a generalization test. The resulting generalization gradient describing response frequency as a function of wavelength approximated a normal distribution centered at the S+.

The form of discrimination training has specific effects on subsequent performance. Hanson (1959) compared generalization gradients obtained in the Guttman and Kalish (1956) procedure with those obtained when intradimensional discrimination training was employed. Four groups of pigeons received intradimensional discrimination training with different wavelengths of light, and responses were reinforced in the presence of the S+ but not in the presence of the S-. For all of the birds the S+ was the illumination of the key with a light of 550 nm, but the S- was varied across the four groups, and was a light of either: 555, 560, 570, or 590 nm. A control group was trained in the presence of the S+, and during the generalization tests, data from the control pigeons formed a curve similar to that obtained by Guttman and Kalish, with a peak of responding at the S+ (550 nm). However, pigeons that had received intradimensional discrimination training responded most to the illuminated key when lit with a wavelength shorter than that of the S+. The size of this peak shift increased as the...
wavelength of the S- was brought closer to the S+ across the four groups of birds that received discrimination training. Peak shift has been found only on intra-dimensional discrimination tasks, where all stimuli used are of the same dimension (Spetch & Cheng, 1998), and has been the subject of considerable experimental and theoretical interest since Hanson’s report (for reviews see Ghirlanda & Enquist, 2003; Honig & Urcuioli, 1981; Purtle, 1973).

The two popular theoretical positions to have emerged as accounts for peak shift are Gradient Interaction Theory (GIT), that is an application of Spence’s classical generalization theory (Spence, 1937), and Adaptation Level Theory, (ALT; e.g., Thomas et al., 1991). According to GIT, peak shift comes about from the interaction of excitatory and inhibitory generalization gradients around the S+ and S-. It assumes that discrimination training establishes an excitatory gradient around the S+ and an inhibitory gradient around the S-. These gradients approximate the form of a normal distribution for response tendency in the presence of an S+ as described by Guttman and Kalish (1956). Algebraic summation of these positive and negative tendencies determines the likelihood of responding at any particular value of the stimulus dimension. If the S- is sufficiently similar to the S+ for its inhibitory strength to be felt at that point of the stimulus dimension, responding at the S+ will be suppressed on testing. Thus, stimuli on the other side of the S+ may elicit more responding than the S+ would itself. Those other stimuli will still have an excitatory tendency from generalization to the S+; however, the inhibitory effect of the S- does not impact them as much as it does the S+. The closer the value of the S+ and S- on the stimulus dimension, the greater this effect should be, and thus, the further the peak of responding will be located from the S+.

ALT offers an alternative explanation of peak shift to that provided by GIT (e.g., Thomas et al., 1991). The distinctive feature of ALT is the proposition that discrimination learning establishes a relation between stimuli, rather than a response to the specific values of those stimuli. To respond appropriately to a test stimulus, this model holds that it is the relation to an adaptation level based on an average of all stimuli experienced by an individual that determines the response. Adaptation level will correspond to the arithmetic average of the S+ and the S- used during training. Participants are assumed to learn to respond to the S+ as a cue that is some distance above (or below) the adaptation level, and not respond to the S- as a cue that is the same distance below (or above) that level. The introduction of novel stimuli during generalization testing results in a change in the adaptation level reflecting the range of these stimuli that typically have a mean value located at the site of the S+ (rather than midway between the S+ and S-). Consequently, responding to the novel stimuli will be shifted away from the actual value of the S+ by whatever that distance is. Peak shift is thus argued to occur because of a change in the adaption level from training to testing, rather than interactions between excitatory and inhibitory gradients.

The underlying assumption when calculating the adaptation level is that it is the arithmetic mean of all stimuli experienced by the individual (Thomas, 1993). The equation for calculating a specific adaptation level is given by Equation 1:

\[ AL = Y(t) = \sum_{i=1}^{t} w(i) f(X(i)) \]  

Where \( Y(t) \) is the average stimulus value, \( f(X(i)) \) is a psychological function that transforms stimuli from physical to subjective scales, and \( w(i) \) is a weight parameter that determines the contribution of stimuli to ALT (Thomas, 1993). Additionally, it is the ordinal position of a stimulus in a sequence that gives the weight of each stimulus in an ordinal series of equally spaced cues when calculating the mean adaptation level. Given these assumptions, it is possible to make quantitative predictions about the effects of different combinations of stimuli on adaptation level that allow different predictions about the shape of generalization gradients from ALT.

Peak shift has been shown to be a general and robust effect that has been demonstrated across multiple dimensions including; faces (e.g., Derenne 2010; Derenne, Loshek & Bohrer, 2015; Spetch, Cheng, & Clifford, 2004), face caricatures (Lewis, 1999), line angles (Bloomfield, 1967; Thomas, Mood, Morrison, & Wiertelak, 1991), spatial location (Cheng & Spetch, 2002; Cheng, Spetch, & Johnston, 1997), and wavelengths of light (Thomas, Windell, Williams, & White, 1985). Furthermore, peak shift has been demonstrated across multiple species including: chickens (Rudolph & Honig, 1972), goldfish (Arnes & Yarzower, 1965), guinea pigs (Thomas & Setzer, 1972), horses (Dougherty & Lewis, 1991), monkeys (Moody, Stebbins, & Iglauer, 1971), pigeons (Hanson, 1959), and rats (Thomas & Setzer, 1972), as well as humans (e.g., Derenne 2010; Lewis, 1999; Spetch et al., 2004; Thomas et al., 1991).

Peak shift is also affected by the range of stimuli used during training and testing (e.g., Derenne, 2006; Derenne, 2019; Derenne et al., 2015; McLaren & Mackintosh, 2000; Wisniewski, Church, & Mercado, 2009), and if the stimuli are arranged simultaneously or successively (Derenne & Gamett, 2016). It is from experiments that have manipulated the relative positions of the S+ and S- that the most convincing evidence supporting ALT has been reported. Specifically, Thomas et al. (1991) produced a peak shift effect towards — rather than away from — the S-. GIT does not predict such a result. Thomas et al. (1991) trained one group of participants (Group S2+S4-) to respond to the 2nd member of a series of 11 light intensity stimuli, and not to respond to the 4th member of the same series. Another group of participants (Group S4+S2-) was trained to respond to the 4th member of that series, and not to respond to the 2nd member. GIT predicts that the generalization gradient for Group S2+S4- should have a peak below that of S2, while that of Group S4+S2- should have a peak above S4.
In contrast, when applied to the stimulus values used by Thomas et al., Equation 1 predicts that Group S2+S4- group would have a generalization gradient that was just below the new adaptation level (6) at a stimulus value of 4.2. Group S4+ S2- are predicted to respond maximally to a stimulus value of 6.2, which is above the adaptation level. Thomas et al. (1991) found that the generalization gradients for both groups shifted to a value larger than 2, in a manner that was consistent with predictions of ALT. Those shifts are fundamentally inconsistent with GIT because for one condition the peak shifted toward, rather than away from the, S-.

Bizo and McMahon (2007) replicated Thomas et al.’s (1991) general finding with human participants using temporal cues. Test stimuli consisted of presentations of a red square for different durations from .38 sec (S1) to 2.37 sec (S11). In their Experiment 3, participants were trained in a go-no-go discrimination task in two conditions, counterbalanced in order of presentation. In Condition S2+S4- the correct stimulus for responding in the training phase was S2 (.46 sec) and responses to S4 (.66 sec) were incorrect. In Condition S2- S4+, these relations reversed. Following discrimination training responding to all 11 stimuli was examined in a generalization test. The peak of the generalization function shifted away from the S+ in the opposite direction to the S- in condition S2-S4+, as both GIT and ALT would predict. However, in Condition S2+S4- the peak of responding shifted towards the S-, falling between the S+ and S-. This result is incompatible with GIT. Although this would appear to favor the ALT account, it does not provide compelling evidence for this theory, as ALT predicted a much more substantial shift of the peak than was obtained. In their discussion, Bizo and McMahon speculate that this discrepancy might have resulted from participants using a strategy such as counting — that would have improved their timing accuracy and would have offset the impact of the adaptation level change following training.

Consequently, in Experiment 1 we replicated the Condition S2+S4- from Bizo and McMahon’s (2007) Experiment 3 but using a more restricted range of time intervals (252 ms to 1554 ms) in an attempt to reduce the potential impact of counting that Bizo and McMahon had speculated might have attenuated the effect they observed. If counting had influenced the performance of Bizo and McMahon’s participants then limiting the possibility of participants counting should result in the peak of the generalization function shifting further away from the S+ than it had in their experiment.

One of the assumptions of both mathematical approaches to discrimination learning described above (GIT and ALT) is that stimuli can be characterized as lying on some continuous dimension, rather than being treated as belonging to discrete categories (Thomas, 1993). There is some evidence that peak shift is lost if participants treat stimuli as if they belong to distinct categories. For example, Spetch and Cheng (1998) attempted to obtain a peak shift to temporal stimuli in pigeons. They reinforced pigeons’ key pecks following a timed duration (S+), but not following another duration (S-). No peak shift occurred, and the generalization gradients were more similar to a step function than the typical Gaussian distribution. The pigeons responded at low rates in the presence of the S- and all stimuli that were more similar to the S- than the S+.

Similarly, the pigeons responded at high rates in the presence of the S+ and all stimuli that were more similar to the S+ than the S-. Spetch and Cheng (1998) hypothesized that the pigeons treated the durations as belonging to one of two categories, either ‘S+-like’ or ‘S-’-like. The physical features of line angles have previously been used by others with humans to encourage categorization through direct instruction (Thomas & Thomas, 1974). Furthermore, humans are relatively accurate when categorizing time durations as either longer or shorter (Rakitin, Gibbon, Penney, Malapani, Hinton, & Meck, 1998). One of the early processes of categorization used by humans is to categorize using the formal characteristics of stimuli, such as color or shape (Griffith & Dougher, 2002), and categorization is said to have occurred when physically different stimuli are processed as if they were the same because they possess similar features or have similar functions (Shafto & Coley, 2003). Previous studies (e.g., Spetch & Cheng 1998; Thomas & Thomas, 1974) have shown that categorical stimuli can negate a peak shift effect; however, more evidence is needed to confirm the generality of this claim and if it is an effect that occurs spontaneously or requires specific stimulus arrangements or instructions.

**Experiment 1**

Experiment 1 investigated the generality of peak shift, by establishing whether peak shift occurs on temporal, line angle and compound line angle and temporal stimuli. A go-no-go discrimination task was used in a within-groups design where participants were asked to respond to an S+ and not to any other stimulus in each of four separate conditions. Two conditions assessed temporal peak shift, one condition tested peak shift with line angles, and one other condition tested peak shift with compound stimuli of duration and line angle. A peak shift effect was expected when temporal stimuli and line angle stimuli were used, but not when compound stimuli were used.

The absolute and relational accounts of peak shift offered by GIT and ALT both make directional predictions regarding shifts in the generalization gradients see Table 1. GIT predicts that for the S8+S10- condition the peak of the generalization gradient would shift to a stimulus value less than 8, and for the S8-S10+ condition, the peak of the generalization gradient was predicted to shift to a stimulus value greater than 10.

ALT, in comparison, allows for quantitative predictions. ALT predicts that after the training phase, the AL will be 9. The difference between both S+ and the AL is 1.
Therefore, the response rule would be to respond to a stimulus that was equal to the AL plus 1 in the S8-S10+ condition and to respond to a stimulus that was equal to the AL minus 1 in the S8+S10- condition. During testing the AL is assumed to shift towards the mean of all stimuli experienced, that is, all stimuli in the training and testing phases. After generalization testing, the AL is calculated to be 6.98. The appropriate response rule learned during training was to respond to the AL +/- 1. Therefore, responding is predicted to peak at 5.98 (6.98 - 1) in the S8+S10- condition, and at 7.98 (6.98 + 1) in the S8-S10+ condition. Furthermore, for the S8-S10+ condition, the absolute and relational accounts offered by GIT and ALT, respectively make opposing predictions.

Method

Participants

Twenty-four students of Southern Cross University participated voluntarily after giving their informed consent. There were 15 females (ages ranged from 18 to 32 years, $M = 21.7$ years, $SD = 3.2$ years) and 9 males (ages ranged from 19 to 23 years, $M = 20.9$ years, $SD = 1.5$ years).

Apparatus

The experiment was conducted in an experimental cubicle (dimensions 3.5m x 4.5m x 5m) that was lit by an overhead light. An IBM compatible computer (Intel Pentium (4) 1.6 GHz, 256 RAM, operating Windows 2000, 1024 x 798 pixel 16 bit color screen with 75 Hertz refresh rate) controlled and recorded experimental events, and a button box (Psychology Software Tools serial response button box, model 200a) was used to record responses. The experimental procedure was written in E-Prime (Psychology Software Tools, E-Prime 1.1(1.1.4.1)), providing millisecond timing accuracy of all events.

The stimuli for two conditions consisted of a 100 x 100-pixel pale blue square displayed in the center of a black background for various durations. The duration of presentation of the square varied to create 11 distinct stimuli. In Condition 1 the S+ was the 8th stimulus, and the S- was the 10th stimulus from the series of 11 stimuli used during generalization testing. In Condition 2 the S+ was the 10th stimulus, and the S- was the 8th stimulus from the series of 11 stimuli used during generalization testing. The stimulus presentation durations for Conditions 2 and 2 are summarized in Table 2.

In Conditions 1 and 2, the following instructions were displayed to the participants on the computer screen:

“This is an experiment on time perception. Your task is to discriminate between a ‘test’ duration and a series of other durations. A blue square will be presented repeatedly for different durations on this screen. The first square you will see will be presented for the test duration. Remember this duration, as you will have to distinguish it from other stimulus durations during the experiment. Press any key to proceed.

When you recognise the ‘test’ duration PRESS the response button. If a subsequent duration is different from the test duration DO NOT press the button. After the stimuli have been presented, try to respond as quickly and accurately as you can. You will receive feedback if you are correct or incorrect on the first few trials; then you will continue without further feedback. Do you have any questions?”

In Condition 3 (line-angle condition), the stimuli were white lines displayed in the middle of a black background at various angles for 1078 ms. All line-angle stimuli were 100 pixels long, 5 pixels wide, and had a resolution of 72 pixels. The line angles were rotated counter-clockwise from the horizontal by the designated degrees (see the fourth column of Table 2), and the S+ was the 8th stimulus, and the S- was the 10th stimulus from the series of 11 stimuli used during generalization testing. In Condition 4, the line angle stimuli that used in Condition 3 were paired with the stimulus presentation from Conditions 1 and 2 (see the fifth column of Table 2). In the time/line-angle condition (Condition 4), the S+ was the 8th stimulus (896 ms and 55°), and the S- was the 10th stimulus (1288 ms and 65°) from the series of 11 stimuli used during generalization testing. The stimulus presentation durations for Conditions 3 and 4 are summarized in Table 2.

In Conditions 3 and 4, the following instructions were displayed to the participants on the computer screen:

“This is an experiment on stimulus generalisation. Your task is to discriminate between a ‘test’ line angle and a series of other angles. The first line angle you will see will be the test angle. Remember this angle, as you will have to distinguish it from other angles during the experiment. Press any key to proceed.

| Account | Condition | S8+S10- | S8-S10+ |
|---------|-----------|---------|---------|
| Absolute Account (GIT) | <8 | >10 |
| Relational Account (ALT) | 5.98 | 7.98 |
| Predictions for the peak of the generalization gradient following generalization testing according to the absolute and relational accounts of peak shift. | | | |
When you recognize the 'test' angle PRESS the response button. If a subsequent angle is different from the test duration DO NOT press the button. After the stimuli have been presented, try to respond as quickly and accurately as you can. You will receive feedback if you are correct or incorrect on the first few trials; then you will continue without further feedback. Do you have any questions?

Procedure

Participants were instructed to press the response button following the presentation of the test stimulus, and not to press the response button following stimuli that were not the test stimulus. Participants received feedback during the training phase, but not during testing. The word “Correct” was displayed in green font on the center of the black background when participants pressed the response button after the test stimulus, or when they did not press the response button after a stimulus other than the target (after 2-s). When participants did not press the response button after the test stimuli, or they pressed the response button after a stimulus other than the target stimulus, the program displayed the word “Incorrect,” in red font on the center of the black background. Participants were then instructed to press any keyboard key to start the training trials, where the S+ and S- were presented on 16 occasions each for a total of 32 training trials. The trial type was selected at random from a list without replacement by the software on each trial. Two participants made more than 20% errors in the last eight training trials, and their data were excluded from the analysis.

After the training trials, the testing phase commenced. The testing phase consisted of 66 test trials. Each of the 11 test stimuli was presented six times in a random order. Participants no longer received feedback on their responses during the test phase. Each participant completed all four conditions in a randomized order, with a brief rest break between conditions.

Results and Discussion

The generalization data for individual participants were averaged separately for all four conditions. The generalization gradients for the temporal stimuli are shown in panel A of Figure 1, and for the line angle and compound/line angle conditions in panel B of Figure 1. The generalization gradients show the average number of times each stimulus was reported as the S+ duration. The minimum number of possible responses was 0, and the maximum number of possible responses was 6. When participants were trained to respond to the S8+, and not to the S10- they subsequently responded more to shorter rather than longer stimuli during generalization testing. When participants were trained to respond to the S10+, and not to the S8- they subsequently responded more to longer rather than shorter stimuli during generalization testing.

The weighted average of each frequency distribution that the generalization represent was calculated for each participant for each condition using the stimulus number as the dimension on the x-axis to allow of direct comparison across conditions where the actual stimulus dimensions differed. There was a significant difference between the mean of the generalization gradient of the S8+S10- (M = 6.75, SD = 0.98), and its S+ (t(23) = -6.26, p < 0.005). Similarly, there was a significant difference between the mean of the generalization gradient of the S8- S10+ condition (M = 9.09, SD = 1.39), and its S+ (M = 10), (t(23) = -3.20, p < 0.01). Therefore, a peak shift was obtained for the S8+S10- condition and the S8-S10+ condition.

| Stimulus Number | Condition 1 Presentation Time (ms) | Condition 2 Presentation Time (ms) | Condition 3 Degrees of Rotation | Condition 4 Degrees of Rotation and Presentation Time |
|-----------------|-----------------------------------|-----------------------------------|--------------------------------|--------------------------------------------------------|
| S1              | 252 ms                            | 252 ms                            | 20 °                            | 20 °, 252 ms                                            |
| S2              | 294 ms                            | 294 ms                            | 25 °                            | 25 °, 294 ms                                            |
| S3              | 350 ms                            | 350 ms                            | 30 °                            | 30 °, 350 ms                                            |
| S4              | 434 ms                            | 434 ms                            | 35 °                            | 35 °, 434 ms                                            |
| S5              | 518 ms                            | 518 ms                            | 40 °                            | 40 °, 518 ms                                            |
| S6              | 616 ms                            | 616 ms                            | 45 °                            | 45 °, 616 ms                                            |
| S7              | 742 ms                            | 742 ms                            | 50 °                            | 50 °, 742 ms                                            |
| S8              | 896 ms (S+)                       | 896 ms (S-)                       | 55 ° (S+)                       | 55 °, 896 ms (S+)                                       |
| S9              | 1078 ms                           | 1078 ms                           | 60 °                            | 60 °, 1078 ms                                           |
| S10             | 1288 ms (S-)                      | 1288 ms (S+)                      | 65 ° (S-)                       | 65 °, 1288 ms (S-)                                      |
| S11             | 1554 ms                           | 1554 ms                           | 70 °                            | 70 °, 1554 ms                                           |

Table 2 Summary of stimulus conditions showing the stimulus number and the stimulus presentation duration for Conditions 1 and 2, the degrees of rotation from the horizontal for Condition 3, and the degrees of rotation from the horizontal and the stimulus presentation duration for Condition 4. The stimuli that served as the S+ and S- stimuli each condition are given in parentheses.
The means of the generalization gradients predicted by the absolute and relational accounts were compared against the obtained means of the generalization gradients for both conditions. The most important condition for this experiment was the S8-S10+ condition when the two accounts made different predictions (see Table 1). GIT predicted the SS8-10+ generalization gradient to peak at a value greater than 10, whereas the ALT predicted the generalization gradient to peak at 7.98. The mean of the generalization gradient for S8-S10+ does not support GIT because the mean was not greater than 10 — (M = 9.09, SD = 1.39). The mean of the generalization gradient was positioned at a point in a direction away from the S+ towards the prevailing AL. However, the predicted means were significantly larger than the obtained means for the S8-S10+ condition (t(23) = -3.20, p < 0.01). Therefore, the results support the ALT over the GIT; however, the magnitude of the peak shift was not as large as predicted by the ALT.

Both GIT and ALT predicted the S8+S10- generalization gradient to peak at a value less than 8. The mean of the generalization gradient for S8+S10- (M = 6.75, SD = 0.98) satisfies predictions of both the GIT and the ALT because the mean of the generalization gradient is at a point that is in a direction away from the S+ towards the prevailing AL (see Figure 1). The observed means of the generalization gradients were significantly smaller than the means predicted by ALT for the S8+S10- condition (t(23) = -6.26, p < 0.01). Therefore, the magnitude of the peak shift was not as great as predicted by the ALT.

The angle condition was hypothesized to produce a peak shift, whereas the compound condition would not. In order to compare the two distributions the mean of the generalization gradients was calculated (Angle: M = 6.62, SD = 1.31; Compound: M = 6.91, SD = 1.06). There was no significant difference between the two means (t(23) = -1.08, p > .05).

Therefore, whether the participants were responding to line angles or line angles and time made no significant difference to their pattern of responses. The use of a more restricted range of temporal cues, that had been expected to limit opportunities for participants to employ counting as a strategy, appears to have had little effect upon the peak of the generalization function as Bizo and McMahon (2007) speculated it might. The use of compound stimuli failed to prevent a peak shift effect as might have been expected if the line angles were treated as categorical stimuli by the participants.

### Experiment 2

In Experiment 2, we ran an additional condition with new participants and so that we could assess if explicit instructions to categorize stimuli would attenuate the peak shift effect. Our use of a within-subject design in Experiment 1 is a somewhat unusual approach in the stimulus generalization literature as it leaves open the possibility that there could be carryover effects or order effects which we attempted to guard against by randomizing the order of presentation of conditions across participants. Consequently, the intention was to expose a group of participants, that had not taken part in Experiment 1, to the same line angles as used in one condition from Experiment 1, but give them explicit instructions to treat those stimuli as hands on a clock. This manipulation would allow us to assess if treating the stimuli as categorical would attenuate...
or prevent peak shift when compared to performance from the equivalent condition without labeling from Experiment 1.

There is preliminary evidence to suggest that in wavelength generalization tasks labeling the S+ influences the pattern of subsequent responding by making the generalization gradient sharper, and centered at the labeled stimulus (e.g., Doll & Thomas, 1967; Thomas & Bistey, 1964; Thomas & Mitchell, 1962). Furthermore, Thomas and Thomas (1974) used labeling to induce a categorization effect using various line tilts explicitly. They used two groups to test this. Group one was given instructions to remember the line angle, as they would need to recognize it further into the experiment. Group two were required to visualize the angle as hands on a clock face, and hence, most participants labeled the stimulus as a particular time. It was hypothesized that through the use of labels, group two created qualitative categories. Consequently, their results showed that peak shift was observed for their group one; however, because of categorization of the stimuli, peak shift was not observed for their group two. Therefore, it was hypothesized in the present experiment that participants labeling stimuli would implicitly categorize, and hence peak shift would not occur.

Method

Participants

Twenty-four students of Southern Cross University participated voluntarily after giving their informed consent. There were 15 females (ages ranged from 20 to 58 years, \(M = 28.7\) years, \(SD = 11.5\)) and 9 males (ages ranged from 20 to 58 years, \(M = 27.6\) years, \(SD = 12.2\)).

Apparatus

The apparatus was the same as that used in Experiment 1. The stimuli were the same as those used in Condition 3 of Experiment 1. The line-angle stimuli were 100 pixels long.

Procedure

The procedure was the same used in Condition 3 of Experiment 1, with an exception that these participants and only experienced one condition were instructed to label the test line angle as hands on a clock: “Some people find it helpful in trying to remember the test line angle as hands on a clock. Try this yourself. What time would it be if the hand or hands were pointed in this way?” All other aspects of training and instruction were the same as for Conditions 3 and 4 of Experiment 1.

Results and Discussion

To assess the effect of providing explicit instruction to participants to treat the stimuli as hands on a clock we compared their performance to participants from Condition 3 in Experiment 1 who experienced the same stimuli, line angles, but without any explicit instruction to label the stimuli as hands on a clock. The mean of the generalization gradient to the clock face condition (\(M = 7.87, SD = 0.86\)) was significantly greater than that of the line-angle condition (\(M = 6.62, SD = 1.31\)) from Experiment 1 \(t(46) = 3.92, p < .005\). It appears that, as anticipated, participants given instructions to label the line angles as if they were hands on a clock face did not show evidence of peak shift (see Figure 2).

The reaction times of participants given instructions to label the line angles as if they were hands on a clock face were compared to those of the angle group to assess if motivation or attention affected the clock face group. It was predicted that if attentional or motivational factors influenced the performance of the clock face group, then their reaction times would be significantly faster than those of the participants in the angle group. To compare the two groups the reaction times for individual participants were averaged separately for the angle (\(M = 562.56\) ms, \(SD = 200.37\)) and clock face groups (\(M = 465.39\) ms, \(SD = 145.82\)). Although the clock face groups’ reaction times were 100 ms faster than those of the angle groups, this difference was not significantly different \(t(46) = 1.92, p > 0.05\). It is unlikely, therefore that the absence of a peak shift effect for the clock face group was caused by increased motivation for the task as the reaction times were not significantly different.

![Figure 2. Mean generalization gradients showing the average number of times a stimulus was reported as the S+ for the Line-angle condition are from Experiment 1, and the Clock face condition data are from Experiment 2. Error bars represent the standard error of the mean.](image-url)
General Discussion

Interest in the study of stimulus generalization has a long history (e.g., see Ghirlanda & Enquist, 2003; Honig & Urcuioli, 1981; Purtle, 1973). That interest continues in part because of the applied importance of developing a deeper understanding of factors that influence stimulus generalization as it might be applied to control generalization for those working in applied behavior analytic settings (e.g., Stokes & Baer, 1977), or where it might impact the ability to recognize human faces (e.g., Spetch et al., 2004), or where it might affect the ability of sniffer dogs to detect odors (e.g., Moser, Brown & Bizo, 2019).

Experiment 1 replicated the observation made by Bizo and McMahon (2007) that generalization testing with an asymmetrical extended set of test stimuli following a temporal discrimination task can in certain circumstances result in a peak shift towards the S-. ALT can account for shifts of generalization gradients towards rather than away from the S-. However, GIT does not predict such a result. One possible confounding influence in both the present Experiment 1 and Bizo and McMahon is the possibility that participants may have used some form of categorization in making their judgments as this would attenuate any peak shift effect, as had previously been reported by Spetch and Cheng (1998). Consequently, Experiment 1 also investigated whether the use of compound cues increased the likelihood of categorization taking place because that would influence peak shift. Very similar levels of peak shift were obtained in this experiment for temporal cues, line-angle cues, and compound temporal/line-angle cues, appearing to indicate that whatever level of categorization might be occurring did not differ across the three cue types. In Experiment 2, however, when participants received explicit instructions to imagine that the line-angle cues were the hands of a clock showing specific times, a peak shift did not occur.

The results from the present experiments support an ALT interpretation instead of a GIT interpretation of peak shift, although the peak shifts were significantly smaller in magnitude than predicted by ALT. ALT predicted the direction of the peak shifts, whereas GIT did not. However, ALT overestimated the amount of peak shift in the conditions using temporal stimuli in Experiment 1. ALT does have some limitations that are worth noting. For example, the AL is a moving average, and there is difficulty in estimating an AL combining the training and testing stimuli, as there are no obvious criteria for determining how much weight to give the training experience in the AL calculation. Furthermore, the size of X in the AL + X decision rule is subject to context effects, such as the amount of training and amount/type of instructions. It is because of these limitations that ALT predictions are based on the ordinal position of the stimulus rather than their absolute value (Thomas, 1993). Thomas (1993) and Thomas et al. (1991) have argued that adaptation develops gradually during testing. It is possible in the present experiment that participants did not receive enough training and experience with the stimuli before testing. Insufficient training would attenuate a peak shift effect, and produce results smaller in magnitude than ALT predicts. An additional experiment that varied the relative numbers of training and test stimuli while maintaining a constant adaptation level could test this assumption.

Another explanation for the smaller than predicted peak shifts could be that participants may have created strategies to help them recognize the S+. In the present experiments mediating strategies were not explicitly controlled or prevented. A common mediating strategy that aids timing is counting (Petrusic, 1984). It is possible that participants were using mediating strategies such as counting to enhance performance. One way this could have been controlled for would be to require participants to read aloud distracter digits, as this has been shown to attenuate timing accuracy (Rakitin et al., 1998). If the peak shift was interrupted because participants mediated their performance by use of some verbal rule or strategy, blocking the mediation strategies should promote peak shift. Another explanation for the smaller than predicted shifts is that implicit categorization was working in opposition to ALT. For example, the above mediating strategy of counting may have implicitly turned the continuous stimulus range into a categorical one.

There is evidence in wavelength generalization tasks that the labeling of the S+ influences the pattern of subsequent responding by making the generalization gradient sharper, and center on the labeled stimulus (e.g., Doll & Thomas, 1967; Thomas & Bistey, 1964; Thomas & Mitchell, 1962). Also, Thomas and Thomas (1974) used labeling to induce a categorization effect using various line tilts explicitly. They found that the group required to categorize the S+ failed to produce a peak shift effect, whereas the group not required to categorize did produce a peak shift effect. Therefore, Experiment 2 was designed to investigate whether the explicit categorization of the continuous stimuli would affect the peak shift effect. As was predicted, the labeled stimuli prevented peak shift. Our prediction assumed that when stimuli were labeled, it would encourage participants to categorize the stimuli.

It is possible that peak shift was observed in the time/line-angle condition of Experiment 1 — where compound stimuli were used — because participants attended to only one stimulus dimension. If participants did not treat the compound stimuli as discrete categorical stimuli that might explain why peak shift was not prevented. Alternatively, it may just be that compound stimuli do not produce a categorization effect, and that is why they did not prevent peak shift. An additional experiment with a condition giving each line angle many different time durations and another condition giving each time duration many different angles could determine if participants
were attending to one stimulus dimension more than the other. If participants had mediated their timing performance by counting that may have allowed them to treat the different stimuli as categorical stimuli. However, there was no evidence that participants spontaneously did this. Also, when a temporal dimension was added to line durations, a peak shift was still observed. The use of compound stimuli failed to prevent a peak shift. However, this may have been because participants were attending to one aspect of the compound more than the other.

In conclusion, the present experiments demonstrate the generality of the peak shift effect. A peak shift effect was observed using temporal, visual, and compound stimuli, thereby supporting the generality of the peak shift phenomenon. Future research might examine the role of verbal mediation and the impact of categorization on peak shift specifically, and what factors promote and attenuate peak shift generally.

**Data Availability** The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

**Compliance with Ethical Standards**

All procedures performed in studies involving human participants were conducted following the ethical standards of Southern Cross University where this research was conducted and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

**Conflict of Interest** On behalf of all authors, the corresponding author states that there are no conflicts of interest.

**Informed Consent** Informed consent was obtained from all individual participants included in the study.

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