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# Conditioning a discriminated eye-blink response to the 'truth value' of statements

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**Abstract**

Two experiments examined the conditioning of a discriminated eye-blink response to the abstract property of 'truthfulness' in visually presented verbal statements. Learning was assessed with a measure of change in eyelid activity following conditioned stimulus (CS) presentations. In the first experiment, a list of randomized statements was presented, half of which were true, and half of which were false. Each false statement in this experiment was paired with a corneal air-puff (the US). The second experiment used the same procedure to compare true and false statements as conditioned stimuli, except it varied the range of CS-US intervals employed. The results support previous findings by showing that the truth-value of presented statements can serve as a conditioned stimulus in an eye-blink conditioning procedure, and that both true and false statements can serve as conditioned stimuli. The results also show that the inter-stimulus interval is an important factor in such conditioning. Implications for future research, and the interpretation of previous studies exploring similar conditioning, are discussed.

Keywords: Verbal stimuli, conditioning, abstract stimuli, true/false statements.

Investigation of the abstract property of ‘truth’ possessed by some statements has been largely limited to traditional verbal systems, such as logic, discourse, and so on (e.g., Ayer, 1936). In contrast, little research has examined the ways in which ‘truth-value’ may serve as an independent stimulus for behavior (see Grant, 1972) – that is, how and when does ‘truth’ become associated with a particular behavior (DePaulo, Lindsay, Malone, Muhlenbruck, Charlton, and Cooper, 2003; Vrij, 2000). Understanding this topic has implications for theoretical aspects of psychology (e.g., Frith, 2003), and it has recently been addressed through the application of conditioning frameworks (e.g., Plumb, Stewart, Dahl, and Lundgren, 2009; Tomash and Reed, 2013b). There may, of course, be a number of ‘naturally occurring’ processes responsible for the generation of reactions to the truth value of a statement – for example, social processes and factors may be involved – however, it is certainly been demonstrated that the past conditioning history of the individual does appear to play a role in this process (Tomash and Reed, 2013b).

In particular, understanding the nature of the conditioning involved in generating measurable responses, such as autonomic physiological reactions (e.g., galvanic skin conductance or eye-blink) or neurological events (e.g., brain function), to the truth value of a statement has practical applications for ‘lie detection’ technologies (see DePaulo et al., 2003, for an overview), such as the polygraph (Frank and Feeley, 2003; Skolnick 1961; Tomash and Reed, 2013a; 2015) and ‘guilty knowledge’ tests (MacLaren, 2001). The principles of many ‘lie detection’ methods involve detecting physiological changes (e.g., increased skin conductance; increased pupil activity) that may be produced when an individual attempts to be deceptive in an answer to a question (Honts, 2014; Kleiner, 2002; Vrij, 2008). Understanding how such physiological responses become conditioned to these deception responses, which can be regarded as an abstract property of the response, is important for understanding this form of technology (see Tomash and Reed, 2013a; 2015).

If the analysis of how particular ‘physiological’ responses become associated with abstract properties of verbal stimuli is to proceed through a conditioning route, then, it seems important to determine if a well-defined, and easily measurable, responses can be conditioned to the *abstract* property of ‘truthfulness’ in a set of statements. There are cases where a conditioned response has been associated with ‘categories’ of stimuli (e.g., Vaughan, 1984), but it is not clear if such responses were attached to abstract properties defining the category, or to the physical characteristics of each of the individual stimuli involved (see Macphail, Reilly, and Good, 1992). In fact, the literature on conditioning specific responses to abstract properties of stimuli is relatively sparse. Some studies have investigated the role of what Pavlov (1932) called the ‘second signaling system’ (i.e., language) and conditioning (Hayashi, 1968; Parra, Esteves, Flykt, and Öhman, 1997). However, overall, there have been relatively few studies that have explored the conditioning of non-verbal responses to the abstract properties of verbal stimuli (see Fleming, Grant, and North, 1968a; 1968b; Jaffee, Millman, and Gorman, 1966; Tomash and Reed, 2013).

Grant (1972) reviewed the earlier studies, and noted that, although several studies reported positive results, there were some mixed findings in the literature, making precise interpretation of the data difficult. For example, several studies explored the conditioning of differential eye-blink responses to ‘true’ and ‘false’ verbal statements (Fleming et al., 1968b; Jaffee et al., 1966), and to the ‘correctness’ of presented arithmetic problems

(Fleming et al., 1968a). Jaffee et al. (1966; see also Fleming et al., 1968b) conditioned an eye-blink response to instances of verbal deception, by pairing instances of deception with a corneal air-puff. They noted an increase in the eye-blink response following deceptive answers. The study reported by Jaffe et al. (1966) followed only instances of deception with the air-puff, but Fleming et al. (1968a) followed either ‘right’ or ‘wrong’ solutions to mathematical problems with an air-puff, and noted conditioning to either set of cues, which generalized to other ‘right’ or ‘wrong’ answers (as found in a skin conductance procedure reported by Tomash and Reed, 2013a). They noted that the ‘wrong’ solutions produced greater levels of conditioning than the ‘right’ answers. In contrast, Fleming et al. (1968b) noted that when verbal statements were used, true answers produced stronger responses than false answers. This study also noted that the effect seen was stronger for partially reinforced compared to continuously reinforced stimuli. However, Tomash and Reed (2015) found the opposite results with regard to the impact of partial reinforcement using a skin conductance response procedure.

This pattern of results leaves a somewhat empirically unsatisfactory situation in several regards (see also Grant, 1972). For example, it is unclear if conditioning occurs more readily to true or deceptive statements, or whether continuous or partial reinforcement is more effective in this context. Moreover, the nature of the procedures employed in these early experiments makes assessment of the role of several important factors such as the duration of the CS impossible to determine. In all of the studies the CS was presented for rather longer periods of time (around 2s) compared to those CS duration more typically employed in classical conditioning studies (typically around 1s;

Clark and Squire, 1999; Kimble, 1961; Weidemann, Tangen, Lovibond, and Mitchell, 2009).

Of further concern is the suggestion that it is unlikely that a classically-conditioned response could come under the control of an abstract verbal stimulus, such as ‘truth-value’, on theoretical grounds. As argued in Skinner’s *Verbal Behavior* (Skinner, 1957), the amount of conditioning required to bring an operant response under the discriminative control of such an abstract property can be extensive (see Sundberg and Michael, 2001, for a discussion in a different context), sometimes requiring prolonged training under different situations, and using different stimuli containing the same property of ‘truth-value’ (Staats, 1961). Such extensive conditioning may be arranged by the verbal community (Barnes-Holmes, Barnes-Holmes, and Cullinan, 2000; Skinner, 1957), as it is of practical value to the community to apply such an operant contingency (Schlinger, 2008; Tomash & Reed, 2013b). However, such extensive exposure to classical contingencies relating an abstract stimulus, such as truth, with a particular response would be unlikely in the normal environment of an individual. This might suggest that operant, rather than classical contingencies, were at operation in developing control over responses that are related to the abstract properties of a verbal stimulus such as its truth-value. Of course, this theoretical argument does not mean that classical conditioning could not explain some laboratory-based phenomenon related to this form of conditioning, but rather that it is unlikely to be a valid explanation of the ‘real world’ phenomenon.

Given the empirically and theoretically uncertain nature of the data relating to conditioning of responses to abstract properties of verbal stimuli, and their importance in practical terms for deception detection (Frank and Feeley, 2003; Skolnick 1961; Tomash and Reed, 2013a; 2015), the current experiments aimed to re-create the earlier experiments that involved a ‘classical conditioning’ procedure (e.g., Fleming Grant, and North, 1968; Fleming Grant, North, and Levy, 1968; Jaffe et al., 1966) by testing whether a non-verbal response (i.e. an eye-blink) could be brought under the control the abstract property of ‘truth’ in verbal stimuli. It was hoped to replicate and extend these studies by manipulating parameters of the conditioning episode in an attempt both to establish more firmly the phenomenon (see Grant, 1972), and to identify some of the procedural aspects that may be related to showing this effect more strongly and reliably. To this latter end, Experiment 1 examined the impact of the CS duration, and Experiment 2 the impact of partial reinforcement, on the conditioning of an eye-blink response to the truth value of a statement.

## Experiment 1

The first experiment systematically replicated the procedure adopted by Jaffe et al. (1966; see also Fleming et al., 1968b) in order to explore whether a discriminative eye-blink response can be conditioned to the ‘truth value’ of visually presented statements. To this end, a series of novel statements, in which half were true, and half were false, was presented to the subjects. False statements served as the to-be-conditioned stimuli (as employed by Jaffe et al., 1966), and as these have a greater relevance to real-world ‘deception detection’ applications of such procedures. Each false statement was followed by a corneal air puff. Each statement was only presented once to each participant, so that the only common property of these statements was their truth value (true or false).

In the original reports (e.g., Fleming et al., 1968a; 1968b), the duration of the stimulus was thought to be an important factor in establishing the conditioned responses (as reading the statements would require some finite time). For this reason, these studies employed a CS duration of 1900ms – which is outside the typical CS-US interval used in eye-blink conditioning experiments (see Kimble, 1961). The current experiment also adopted this CS duration, but also compared this to the effects noted when a 1000ms CS-US latency was used, which is more typically employed in human conditioned eye-blink experiments (Clark and Squire, 1999; Kimble, 1961; Weidemann, Tangen, Lovibond, and Mitchell, 2009).

This factor seemed important to examine for a number of reasons: firstly, to explore the conditioning of such an abstract stimulus with parameters more typically employed in conditioning studies (Clark and Squire, 1999; Kimble, 1961); secondly, to establish whether there may be some interaction between reading time and conditioning effects (especially given the well documented relationship between language and conditioning); and thirdly, as CS duration effects have been seen to influence rates of conditioning, and a shorter CS is typically associated with stronger classical conditioning effects (Balsam and Gallistel, 2009), it might be expected to produce stronger effects than previously noted in this paradigm, if the mechanism is classical.

## Method

### *Participants*

Seventeen undergraduate psychology students were used in this study (14 female and 3 male), with a mean age of 20.5 ($\pm$ 3.0 SD) years. The participants were recruited through the Psychology Department's online subject pool, and received course credits for their participation in the experiment. All participants provided informed written consent prior to participating. One participant was excluded from the analysis due to an equipment malfunction during their session that made their recorded responses unusable. This left 16 participants for the final analysis. The participants were divided into two groups: 8 received a CS duration of 1000ms, and 8 received a CS duration of 2000ms.

### *Apparatus*

The experiment was conducted in a small room containing a desk and two computers. One computer was used for displaying the stimuli, and the other computer was used for controlling the experiment and monitoring the equipment functioning. Participants were seated facing the display computer, but they could not see the screen of the control computer.

The participants' eye-blink responses were measured using San Diego Instruments Eyeblink Conditioning System© hardware, and the corneal air-puffs were delivered using the corresponding Eyeblink Portable Air Puff Unit©.

A computer program, written with the LabVIEW© programming environment, was used to time the trial events, present the statements on the display monitor, deliver the US, and record the participant's responses.

### *Stimuli*

The conditioned stimuli were short, simple true or false statements (e.g., "*You are sitting in a chair*"), each between 3 and 7 words long (see Appendix A for complete list of statements). Fifty true statements, and fifty false statements, were used for the experiment, and no statement was presented more than once during a session, and these statements were presented in a randomized order for each participant. The statements were presented on a 27cm x 54cm computer monitor, in black text on a white background. They were displayed in Times New Roman regular font, with letters 15mm tall. The US was a corneal air-puff, of 11psi, delivered to the participants' right eye.

***Procedure***

Prior to each experiment, the participants were instructed to pay attention to the statements presented on the monitor, and to "neither aid nor inhibit [their] natural eye-blink responses to the stimuli." They were not given any indication of when the air-puff would be presented, or about the significance of the statements. They were not asked to do anything other than read the statements.

Each participant received 100 trials during a single 25min experimental session. On each trial, the program began recording the participant's response, waited for 2s to establish a baseline reading, and then presented the trial's statement (i.e., the CS) on the display monitor. After the statement had been displayed for the pre-defined duration (1000ms or 2000ms), the program removed the statement, and the screen went blank. On trials where the statement was false (CS+), the program immediately delivered the US on the termination of the CS. If the statement was true (CS-), no air puff was delivered.

Each trial was followed by a randomized inter-trial interval of between 6s and 9s, after which the next trial began.

***Response measures and statistical analysis***

The circuit employed in the San Diego Instruments EBC system outputs a signal proportional to the change in eye closure, with positive representing a closing movement of the eyelid. This allowed the standard deviation of the measured signal to be taken as an indicator of the amount of activity of a participant's eyelid over a given period. To measure the eye-blink response on each trial, we used the SD of the period between 500ms after statement presentation and when the UCS was presented (Figure 1). This procedure meant that any eye-blink responses occurring in the initial part of the CS presentation were excluded from the analyses. This is a usual procedure when excluding voluntary eye-blinks that are not taken to be related to the classical conditioning procedures under study. Thus, trials were excluded from analysis when responses had a short latency (i.e., they began more than 500ms before the US) and were maintained until the onset of the US (Spence & Ross, 1959).

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Figure 1 about here

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As noted by Blumenthal, Cuthbert, Filion, Hackley, Lipp, and Van Boxtel (2005) wide individual differences exist in absolute blink magnitude that are unrelated to the experimental manipulations undertaken. Accordingly, blink magnitudes may result in a small number of subjects disproportionately affecting the outcome. Due to this, standardized blink magnitudes are typically employed. To standardize this value across participants, these measurements were scaled for each participant, to a maximum of 100, using the maximum measured UCR for each participant. The response for each trial was thus acquired using the following equation:

$$\text{Response} = SD(RW_{CR}) * \left[\ 100 / \max(\ SD(RW_{UCR})\right]$$

where: $RW_{CR}$ = Period from 500 ms after CS onset to UCS onset

$RW_{UCR}$ = 500 ms period after UCS onset

For statistical analysis, the trials were broken into ten blocks of 10 trials each, and the responses measured in all CS+ (false statements), and CS- (truthful statements), trials in each block were averaged.

## Results

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Figure 2 about here

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Figure 2 displays the mean magnitude of conditioned responding on each ten-trial block for CS+ (false) and CS- (true) trials. The left panel shows the 1000ms group, in which the US followed 1000ms after the presentation of the statements. The right panel shows the 2000ms group, in which the US followed 2000ms after presentation of the statements.

As can be seen from inspection of the left panel of Figure 2, over the course of training for the 1000ms group, false statement trials (CS+) acquired a slightly stronger eye-blink response than did the trials with true statements (CS-). The data in the right panel (2000ms group) show a stronger discriminatory response to false statements (CS+) than was observed in the 1000ms group. The discrimination with the 200ms group is apparent from the first trial block, however, leaving little evidence of acquisition.

A repeated-measures, mixed-model, analysis of variance (ANOVA), with group as a between-subject factor, and block and CS as within-subject factors, was conducted on these data. This analysis found a statistically significant main effect of CS, $F(1,14) = 19.71$, $p < .001$ (power = .980), *partial* $eta^2 = .585$, but not of block, $F(9,126) = 1.06$ , $p > .30$ (power = .429), *partial* $eta^2 = .070$, nor group, $F(1,14) = 1.10$, p > .30 (power = .112), *partial* $eta^2 = .073$. There were statistically significant interactions between block and group, $F(9,126) = 2.43$, $p < .05$ (power = .887), *partial* $eta^2 = .148$, and between block and CS, $F(9,126) = 1.80$ (power = .735), $p < .05$, *partial* $eta^2 = .114$, and a marginal interaction between CS and group, $F(1,14) = 3.00$, $.08 > p > .07$ (power = .290), *partial* $eta^2 = .177$. There was no three-way interaction, $F(9,126) = 1.02$, $p > .40$ (power = .105), *partial* $eta^2 = .068$.

To further analyze these data, separate two-factor (CS x block) ANOVAs were conducted for each group, as outlined by Howell (1998). The ANOVA for the 1000ms group revealed a statistically significant change in eye-blink activity over blocks, $F(9,63) = 2.74$, $p < .05$ (power = .929), *partial* $eta^2 = .278$, and a statistically significant interaction of block and CS, $F(9,63) = 2.29$, $p < .05$ (power = .861), *partial* $eta^2 = .247$. There was not, however, a statistically significant main effect for CS although the effect size was moderate, $F(1,7) = 2.56$, $p > .10$ (power = .221), *partial* $eta^2 = .267$. Simple effect analyses revealed that the difference between CS+ (false) and CS- (true) statements was statistically significant on trial blocks 4 and 7, inclusive, smallest, $F(1,7) = 9.62$, $p <$

.01 (power = .735), *partial* $eta^2$ = .579. For the 2000ms group, the ANOVA revealed a statistically significant main effect of CS, $F(1,7) = 15.94$ (power = .922), $p < .01$, *partial* $eta^2$ = .695, but did not find a statistically significant change over trial blocks, nor an interaction between the two factors, both *F*s < 1 (power = .170), *partial* $eta^2$s < .010.

## Discussion

This experiment tested whether the effects found in previous studies (e.g., Fleming et al., 1968; Jaffe et al., 1966), which attempted to condition an eye-blink response to the truth-value of statements could be replicated, and whether this effect depended on the use of a relatively long CS duration. This CS-duration factor was important to examine for a number of reasons connected with examining whether the conditioning of abstract stimuli, such as ‘truth value’ could be more strongly related to previous standard conditioning studies. The current results demonstrated that participants in the 2000ms CS condition, as used in the previous studies, began exhibiting a discriminated eye-blink response to false statements very early in the session. This response was maintained in strength over the remainder of the session. Thus, this condition corroborated the previous research (e.g. Fleming, Grant and North, 1968), and suggests that conditioning can occur to abstract stimuli (see also Tomash & Reed, 2013a; Grant, 1972).

It should be noted that in this study there was no condition in which false stimuli are not conditioned with an air puff, and it is always possible that such false statements may be more likely to be followed by such a response prior to conditioning. Of course, there was a change in conditioned responding across trials for the present 1000ms condition, which suggests, that the response is learned. Additionally, Tomash and Reed (2013a) used such a control in a skin conductance procedure, and only noted an effect in the conditioning group. Nevertheless, the inclusion of a control in which no airpuffs are presented should be considered in subsequent studies.

However, the results from the shorter 1000ms condition, which is closer to that period typically used in human eye-blink conditioning procedures (see Clark and Squire, 1999; Weidemann et al., 2009), were not as strong as those for the 2000ms condition. This result appears to be at odds with traditional views of CS duration effects on classical conditioning (Balsam and Gallistel, 2009), and does suggest that other learning mechanisms, such as operant conditioning, may be at play in the current studies.

There are a number of potential considerations concerning the difference in conditioning magnitude between the two CS-durations. The power of the analyses should be noted, and it might be with more participants these non-significant effects would have been significant. Although, it should be noted, that they are of a much smaller effect size than the longer stimulus duration effects. When using such verbal stimuli as a CS, it may be that reading time is an important feature to consider. However, studies of reading speed suggest that about 250 words per min is average in the general population, with around 350 words a min in university students (De Leeuw and De Leeuw, 1965; Fry, 1963). Given this, an average time of 250ms per word would be a conservative estimate of the speed needed, meaning the total phrase should be read in around 1000ms before the ‘truth’ or ‘falsity’ of the statements would become apparent to the participant. This would affect the time between when the CS was ‘presented’ and when the US was delivered. When one takes into account reading time, the interval between CS presentation and US presentation was far shorter than programed.

The suggestion that reading time is important is supported by reports from participants following the experiment, the failure to acquire strong conditioned responses in the 1000ms group may have been due to insufficient time for the participants to respond to the statements. Some participants reported “having to guess” whether some of the statements had been true or false because they did not have time to fully read them. Given that a discriminatory response to the abstract properties of verbal statements would require a time-consuming intervening behavior (reading), the terminal discrimination possible was likely limited by the relatively short duration of the statement presentations.

## Experiment 2

Experiment 1 appeared to show that a conditioned response could be reliably associated with the abstract ‘truth value’ of a statement. However, the former experiment only explored the conditioning of a response to false statements. For both theoretical and practical reasons, previous studies have focused mainly on testing *false* statements as conditioned stimuli (see Grant, 1972, for a review), but it seems important to establish if there are any differences in the ease with which true and false statements can be conditioned. Given this, the second study compared the use of ‘true’ and ‘false’ statements as conditioned stimuli in a procedure similar to that of the first experiment. To this end, for half the participants in the second experiment false statements served as the CS+, and for half true statements served as the CS+.

The current experiment employed an ISI of 2000ms, which had provided better results in the first experiment. In addition, the current experiment also assessed the effect of a partial reinforcement schedule on the conditioning and maintenance of the responding associated with the truth-values of the statements. In part, this manipulation replicated more fully the work of Fleming et al. (1968a), who used a partial conditioning procedure. By showing correspondence between the procedures, the current study attempted to strengthen the converging lines of evidence that truth-value is a conditionable property of a class of stimuli. Also, this manipulation was conducted to indicate if the weaker conditioning in the 1000ms condition in Experiment 1 might be consistent with the effect of a partial schedule (due to some stimuli not being fully read, perhaps producing the impression of a partially reinforced stimulus class), or to the effect of the CS duration *per se*. If it were the latter, then the current study should show strong terminal discrimination in both continuous and partial conditioning.

## Method

### *Participants*

Twelve female undergraduate psychology students were recruited via the same means as in the first experiment. The participants had a mean age of 20.4 ($\pm$ 1.0) years, and each provided written consent prior to participating in the experiment.

### *Apparatus and Procedure*

This experiment was identical to the previous experiment, with two exceptions. In the current experiment, half of the participants received the CS following true statements, and half following false statements.

As in Experiment 1, each participant received 100 conditioning trials. In this experiment, however, on the second 50 trials (trials 50-100) the US was presented on only 50% of the CS+ trials (randomly determined by the program during the session). The statement duration in this experiment was 2000ms for all participants.

## Results and Discussion

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Figure 3 about here

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Figure 3 displays the mean magnitude of conditioned responding on each trial block for CS+ (false) and CS- (true) trials. The left panel shows the false statement group, in which the US followed false statements. The right panel displays the true statement group, in which the US followed true statements.

As can be seen from inspection of the left panel of Figure 3, over the course of the first 50 trials for the false statement group, false statement trials acquired stronger eye-blink response than did the trials with true statements. This response declined over the next 50 trials under partial reinforcement. Similarly, the data in the right panel (true statements reinforced) show the acquisition of a discriminatory response to true statements, compared to false statements, under continuous reinforcement over the first 50 trials, and a decline in the response under partial reinforcement in the second 50 trials.

A mixed-model ANOVA, with truth value (true or false statements as CS+) as a between-subject factor, and block and CS (CS+ versus CS-) as within-subject factors, was conducted on the first 50 trials (acquisition). This analysis revealed a statistically significant main effects of CS, $F(1,10) = 8.00$, $p < .01$ (power = .678), *partial eta*$^2$ = .444, and block $F(5,115) = 3.38$, $p < .05$ (power = .852), *partial eta*$^2$ = .128, but not of truth value, $F < 1$ (power = .089), *partial eta*$^2$ = .004. There was a statistically significant interaction between CS and block, $F(5,115) = 3.78$ $p < .05$ (power = .866), *partial eta*$^2$ = .142, but none of the interactions involving truth value were significant, all $F$s < 1 (powers < .217), *partial eta*$^2$ s < .01.

As can also be seen in Figure 3, the response on CS+ trials drops markedly during the second 50 trials, in which only 50% of the CS+ trials were reinforced. A three-factor mixed-model ANOVA (truth value, CS x block) was conducted on these data and revealed no statistically significant main effects or interactions, all $F$s < 1, *partial eta*$^2$ s < .01.

These results from the 100% reinforcement blocks replicate those noted in Experiment 1, and show a clear effect of conditioning, irrespective of the truth-value of the statement. That suggests that there is nothing intrinsic to these negative statements that would provoke an eye-blink response, such as avoidance of a previously punished statement (see Tomash and Reed, 2013b). Rather, conditioning was noted to the truth value of the statement. However, when a partial reinforcement schedule was introduced, the discrimination was reduced markedly, suggesting that, even with a stimulus-duration long enough to produce an effect, a partial schedule was not enough to support such a discrimination. Of course, this does not necessarily mean that partial reinforcement is the mechanism responsible for the lack of effect seen in Experiment 1 when employing a short stimulus duration (with participants missing some cues due to their short presentation time, and this giving the impression of a partial schedule). The impact of the partial schedule could be independent of that of stimulus duration. However, the effects of both are consistent with one another. It should also be noted that some of the powers associated with the non-significant analyses were low, which suggests that with a large number more participants, an effect might have been seen for these factors – although the size of the effect for these factors is much smaller than those for the factors that proved reliable in the current study.

## General Discussion

The current experiments were designed to explore whether the abstract property of ‘truth value’ among presented statements can be reliably associated with an overt response in an eye-blink conditioning procedure (see Fleming, Grant, and North, 1968; Fleming et al., 1968a; 1968b; Jaffe et al., 1966). The findings suggest that such a response could be conditioned, and can be conditioned irrespective of whether the truth-value was ‘true’ or ‘false’. These findings serve to extend and examine some previous reports of such conditioning (see also Tomash and Reed, 2013a; 2013b; and Grant, 1972, for a review).

Experiments 1 and 2 replicated previous findings that demonstrate that when a relative long CS duration for eye-blink conditioning (2000ms) was employed, a discrimination based on truth value could be acquired (Fleming et al., 1968a; 1968b; Jaffe et al., 1966). In addition, the current studies extended these findings by showing a similar discrimination also could be acquired using a shorter duration CS, which is more in line with typical values used in classical conditioning of eye-blink responses (Clark and Squire, 1999; Kimble, 1961; Weidemann et al., 2009). However, it might be suggested that the terminal discrimination achieved appeared to be less strong with the short ISI, perhaps because this value did not allow participants time to respond to all statements (although, given the difficulties in interpreting the effect of stimulus duration, this should be regarded as a tentative suggestion).

Experiment 2 demonstrated that similar effects could be found with true statements serving as the conditioned stimulus as well as false statements. This replicates work conducted with galvanic skin responses (Tomash and Reed, 2013a), and suggests that the nature of the truth value is not important when using this abstract stimulus as a CS. It also found that these responses strongly decline when put under partial reinforcement, which may go some way toward explaining the rather mixed pattern of results noted by Grant (1972). That is, if shorter duration stimuli are used, that make reading the stimulus harder, and they are partially reinforced as well, it may be that some studies would not generate reliable levels of conditioning to the truth value of the statement.

Future research could rule out the problem of CS duration and reading time by presenting statements on the screen serially as individual words, in which the final word determined the truth-value of the statement, and was more rigidly temporally related to the US onset. The developments of these studies is certainly original in making clear the next step for future research: to find a method of making the temporal requirements of responding to complex verbal stimuli consistent with those of establishing discriminatory conditioned responses.

That an abstract property of a stimulus class can serve as a stimulus in a conditioning experiment raises questions regarding nature of this abstract property. In this case, the conditioned stimuli did not share any physical properties with one another. This suggests that it was the abstract ‘truth-value’ of the stimuli that served as the conditioned stimulus. It is unclear whether stimuli classes connected by other arbitrary relationships would be similarly impacted by such conditioning, or what the limits to the conditioning of arbitrary stimulus properties might be (i.e. would this extent to nonverbal stimuli, or extend to non-humans).

The current study may also have implications for the practical detection of deception and similar procedures. In terms of understanding the relationship between deception and physiological responses, Skinner (1953) suggested that the polygraph measures: “…*emotional responses generated when the individual engages in behavior for which he has previously been punished*” (1953, p. 187). According to this view, the physiological responses exhibited during deception are a conditioned side-effect of previous punishment. Tomash and Reed (2013b) reported evidence consistent with this argument by showing that previous levels of punishment for verbal behavior (swearing) are associated with increased SCRs when that behavior is repeated. The limited consistency and accuracy that troubles the polygraph could be the result of inconsistency in the pairing of deception and any aversive consequences (e.g., deception is not always punished, specifically, when it is undetected). Further research in this area may sharpen and improve the stimulus control acquired by such abstract properties of verbal statements, and utilize them the detection of deception. The demonstrated scope of potential generalization hints at the possibility of generalization crossing the overt/private barrier, as has been shown for the polygraph (see Tomash and Reed, 2013a; 2015). We may soon be able to re-create and, thus, better control, and detect, responses like those used in the polygraph.

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# Figure Captions

Figure 1. Schematic example of trial analysis method. The y axis represents blink magnitude, the x axis represents time. The blue rectangle indicates duration of CS, and the red rectangle indicating duration of UCS. The blue shaded area shows the window in which conditioned responses were measured.

Figure 2. In Experiment 1, graph of averaged eyeblink responses in each trial block with 1000 ms (left) and 2000 ms (right) ISI groups.

Figure 3. In Experiment 2, graph of averaged eyeblink responses in each trial block with false (left) and true (right) statements reinforced. Note that first 50 trials in each group received constant reinforcement, and next 50 received 50% intermittent reinforcement.

Figure 1

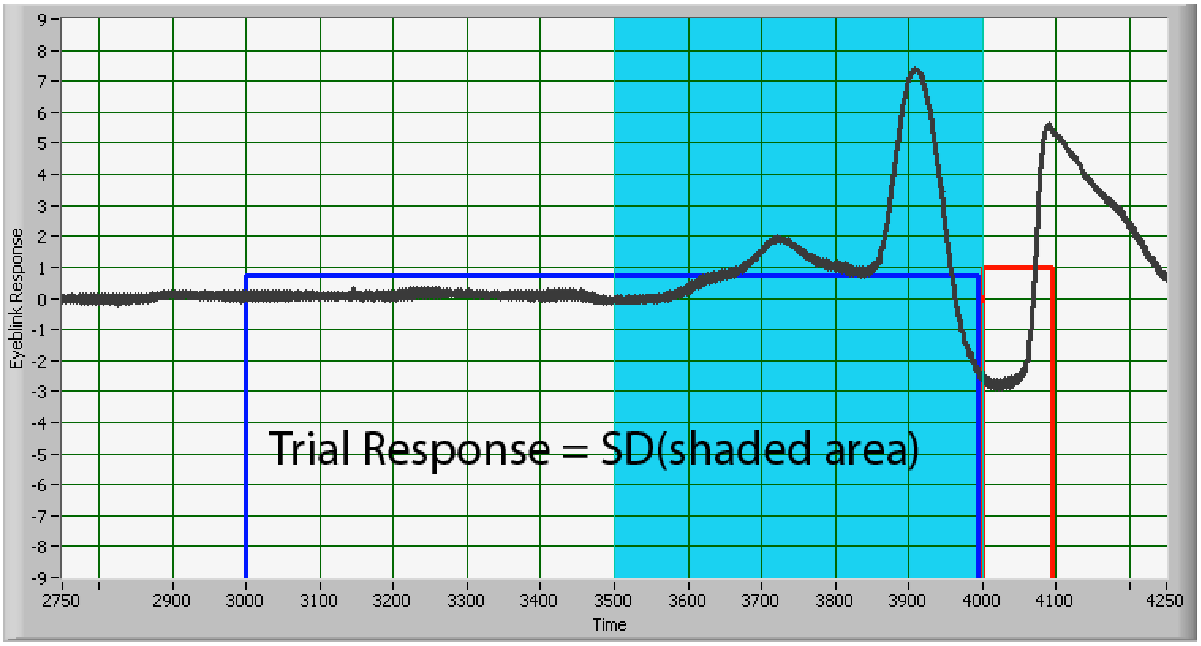

Trial Response = SD(shaded area)
Eyeblink Response
Time
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
2750
2900
3000
3100
3200
3300
3400
3500
3600
3700
3800
3900
4000
4100
4250

Figure 2

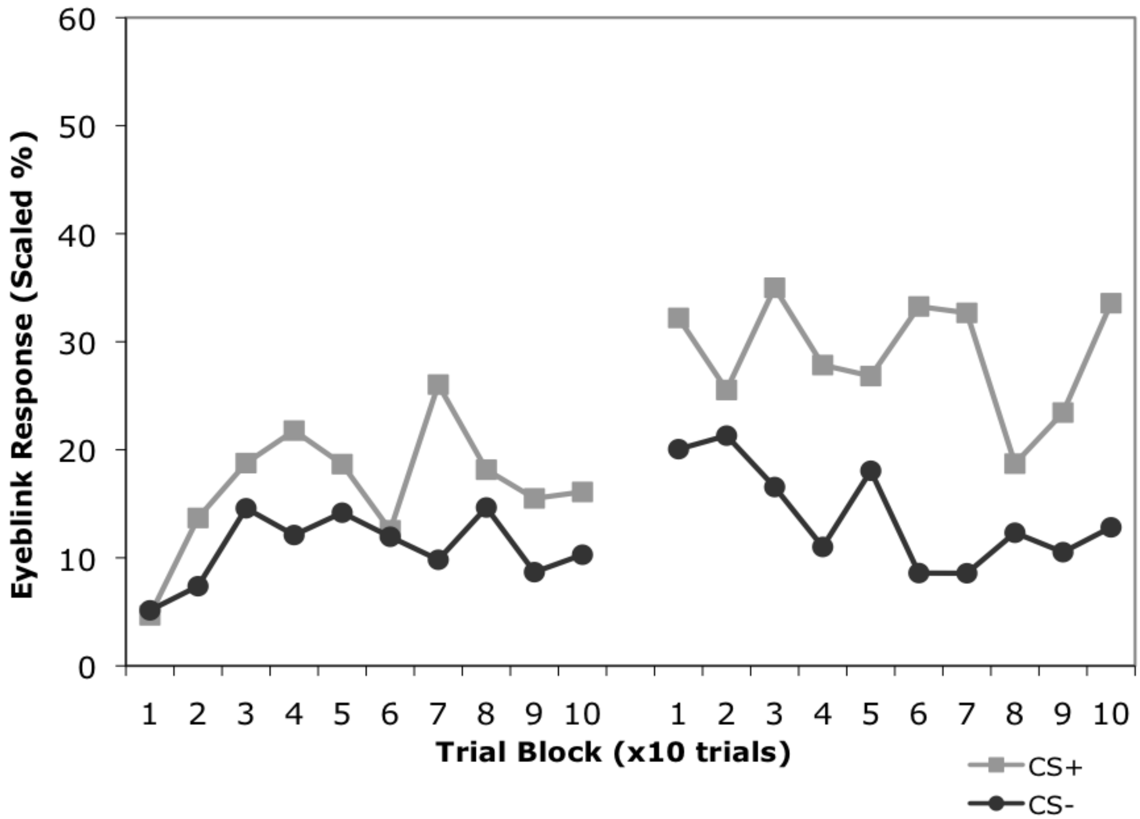
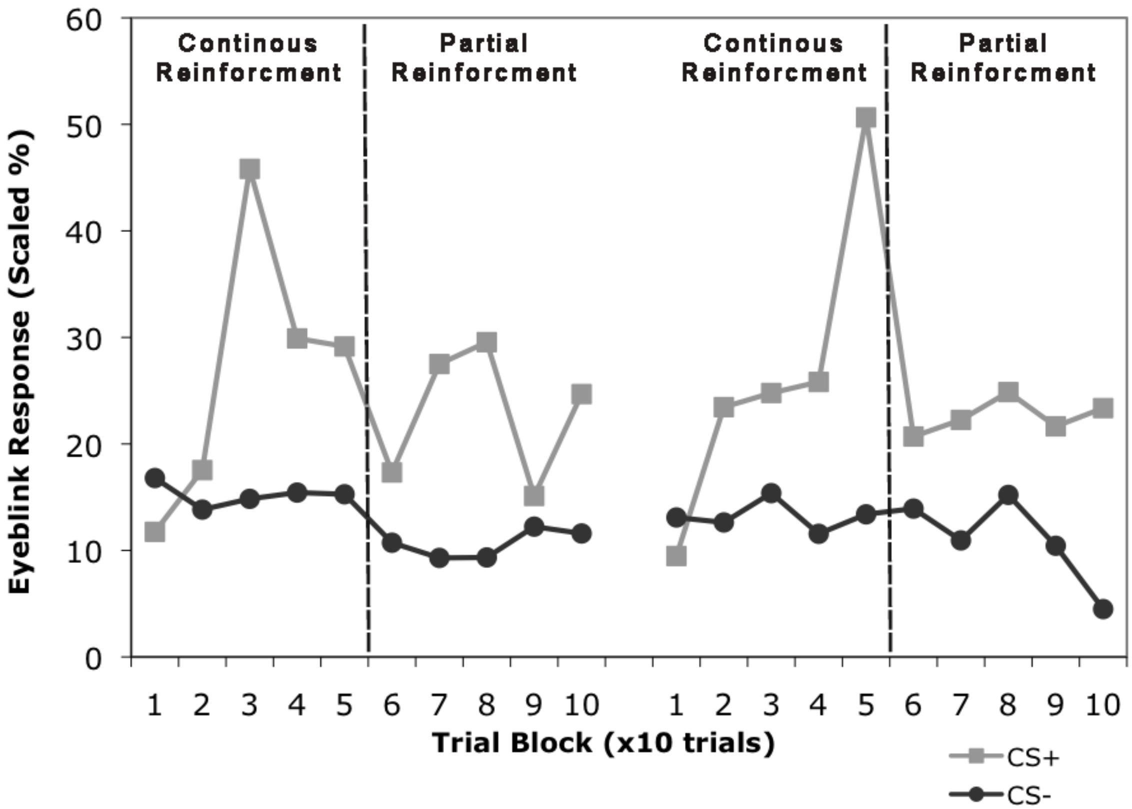

60
50
40
30
20
10
0
Eyeblink Response (Scaled %)
1 2 3 4 5 6 7 8 9 10 1 2 3 4 5 6 7 8 9 10
Trial Block (x10 trials)
CS+
CS-

Figure 3


60
50
40
30
20
10
0
Continous Reinforcment
Partial Reinforcment
Continous Reinforcment
Partial Reinforcment
Eyeblink Response (Scaled %)
1 2 3 4 5 6 7 8 9 10
1 2 3 4 5 6 7 8 9 10
Trial Block (x10 trials)
CS+
CS-

Appendix A: Trial Statements

| **Trial** | **Statement** | **Truth Value** |
|---|---|---|
| 1 | You are sitting in a chair | TRUE |
| 2 | The world is round | TRUE |
| 3 | You are the Queen of England | FALSE |
| 4 | Books have pages | TRUE |
| 5 | You own a kangaroo | FALSE |
| 6 | Acorns are nuts | TRUE |
| 7 | Circles are round | TRUE |
| 8 | This room has a desk | TRUE |
| 9 | Elephants have scales | FALSE |
| 10 | This room is in a building | TRUE |
| 11 | The Sun is smaller than the Earth | FALSE |
| 12 | Humans are green | FALSE |
| 13 | This room has windows | FALSE |
| 14 | The world is flat | FALSE |
| 15 | Sheep have wool | TRUE |
| 16 | Mice are smaller than cats | TRUE |
| 17 | You eat rocks | FALSE |
| 18 | Beer is a liquid | TRUE |
| 19 | Lead is heavier than paper | TRUE |
| 20 | Days are longer than weeks | FALSE |
| 21 | Swansea is in China | FALSE |
| 22 | Strawberries are fruits | TRUE |
| 23 | You are in Australia | FALSE |
| 24 | Grass is blue | FALSE |
| 25 | This room has computers | TRUE |
| 26 | Pigeons are birds | TRUE |
| 27 | You live in an igloo | FALSE |
| 28 | Humans are plants | FALSE |
| 29 | Squirrels are birds | FALSE |
| 30 | Water is a liquid | TRUE |
| 31 | Pigs can fly | FALSE |

| | | |
|---|---|---|
| 32 | Flowers are reptiles | FALSE |
| 33 | The sun orbits the earth | FALSE |
| 34 | Squirrels climb trees | TRUE |
| 35 | Rocks are alive | FALSE |
| 36 | This room is silent | FALSE |
| 37 | Birds have feathers | TRUE |
| 38 | Albert Einstein was a physicist | TRUE |
| 39 | You are an astronaut | FALSE |
| 40 | You are looking at a computer | TRUE |
| 41 | Penguins are reptiles | FALSE |
| 42 | Lead is worth more than gold | FALSE |
| 43 | Humans lay eggs | FALSE |
| 44 | This room has walls | TRUE |
| 45 | Carrots are vegetables | TRUE |
| 46 | Swansea has beaches | TRUE |
| 47 | Humans have feathers | FALSE |
| 48 | Birds have wings | TRUE |
| 49 | Libraries have books | TRUE |
| 50 | You own an island | FALSE |
| 51 | Sheep are mammals | TRUE |
| 52 | Humans need food to survive | TRUE |
| 53 | Jesus was a penguin | FALSE |
| 54 | London is in the U.K. | TRUE |
| 55 | You are younger than 70 | TRUE |
| 56 | You are sitting on a couch | FALSE |
| 57 | You have a head | TRUE |
| 58 | Roses are flowers | TRUE |
| 59 | Paper is heavier than lead | FALSE |
| 60 | The Earth is spinning | TRUE |
| 61 | Bananas are yellow | TRUE |
| 62 | You are a tree | FALSE |
| 63 | London is in Wales | FALSE |
| 64 | Violins are instruments | TRUE |
| 65 | You are a student | TRUE |
| 66 | Paris is in America | FALSE |

| | | |
|---|---|---|
| 67 | Money grows on trees | FALSE |
| 68 | Red is a color | TRUE |
| 69 | You are a sausage | FALSE |
| 70 | Cats are larger than horses | FALSE |
| 71 | China is in Asia | TRUE |
| 72 | The Earth orbits the moon | FALSE |
| 73 | Water is heavier than air | TRUE |
| 74 | You are a human | TRUE |
| 75 | Snow is white | TRUE |
| 76 | You are studying dentistry | FALSE |
| 77 | You are in Wales | TRUE |
| 78 | Bananas are purple | FALSE |
| 79 | The Sun is hot | TRUE |
| 80 | Cars have wheels | TRUE |
| 81 | Humans live under water | FALSE |
| 82 | The sky is blue | TRUE |
| 83 | Lead is heavier than wood | TRUE |
| 84 | Triangles have 3 sides | TRUE |
| 85 | This room is full of water | FALSE |
| 86 | Swansea is in Wales | TRUE |
| 87 | Fish live in water | TRUE |
| 88 | Salt tastes sweet | FALSE |
| 89 | Humans are reptiles | FALSE |
| 90 | Chickens lay eggs | TRUE |
| 91 | London is in China | FALSE |
| 92 | You have 3 eyes | FALSE |
| 93 | You sleep in a bed | TRUE |
| 94 | Humans need air | TRUE |
| 95 | You sleep in a pile of hay | FALSE |
| 96 | Keyboards have buttons | TRUE |
| 97 | Pens have ink | FALSE |
| 98 | Fire is cold | FALSE |
| 99 | Humans are mortal | TRUE |
| 100 | This room has no ceiling | FALSE |