*The effect of Before and After instructions on the speed of sequential responding.*

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Order judgements are slower and less accurate when reversed. That is, when participants see two events in a sequence (e.g., circle …square), they are quicker to report Before statements (e.g., "Circle before Square") than After statements ("Square After Circle"). The current study sought to determine whether a reversal effect would also occur when participants are instructed to produce a sequence of responses. Twenty participants were trained to criterion on simple Before and After instructions that specified sequences of two responses (e.g., "Circle *before* Square"). In a subsequent test, participants produced instructed sequences (e.g., circle … square) more quickly and more reliably when instructed to choose one stimulus *before* another than when they were requested to choose one stimulus *after* another. The implications of these findings for current theories of relational responding are considered.

Key words; before, after, sequential responding, temporal instructions, relational responding, mutual entailment.

Humans demonstrate remarkable flexibility in their ability to respond to complex patterns of stimuli and to produce complex sequences of responses. Indeed, this flexibility has led to heated debate about exactly how such complexity of control is established. One of the earliest understandings of how sequences of behaviour are controlled was chaining. Chaining theories (e.g., Ebbinghaus, 1964/1885; Hull, 1932) contended that understanding a stimulus sequence was simply a sequence of responses occurring as the stimuli were presented (S1-S2-S3 occasions R1-R2-R3). Through repetition, an element of a response sequence (e.g., R2) then becomes a discriminative stimulus for the later responses in that sequence (e.g., R3), but not the earlier responses (e.g., R1). Over time, the probability of producing appropriate response sequences increases.

Skinner (1969) suggested an alternative account, that instructions involved discriminative responding, shaped by reinforcement of compliance. For Skinner, rules act as verbal specifications for contingencies of reinforcement, controlling behaviour in the absence of feedback before a consequence is given. However, novel instructions can control behaviour in the absence of differentially reinforced responding. To supplement Skinner's account, Cerutti (1989) argued that stimulus control by novel instructions can result from the combination of instruction sequences that have been previously reinforced. Dermer and Rodgers (1997) demonstrated that novel combinations of familiar verbal stimuli could effectively control sequences of responses. Specifically, they employed instructions consisting of spelling out number strings between 0 and 99999 (e.g., ONE-THREE-FOUR-TWO-EIGHT). During training, either continuous or intermittent reinforcement was delivered contingent on a chain of 'buying' and following instructions (pressing the numbers on a keypad). In this experiment, the numbers constituted pre-experimentally established discriminative stimuli that were arranged in novel orders within the experiment. As the

numerical instructions involved in this study were rarely repeated across trials, the control exhibited by the numerical values cannot be a result of a previous history of reinforcement of the whole sequence.

Hayes, Thompson and Hayes (1989) demonstrated control by novel instructions in which the constituent stimuli of the instructions participated in equivalence classes. Rules typically consist of novel combinations of familiar stimuli, and members of a previously trained equivalence class may constitute an example of a rule. In Experiment 1, participants were trained on a 'timing' task involving both note position on a musical staff and related tones of different durations, and a 'placement' task, involving differing pitches of notes and their corresponding keys on a piano. Three conditions were used in the experiment, training on the 'timing' and 'placement' classes alone, and both. Participants were instructed to play particular pieces on the piano, with participants exposed to 'timing' training demonstrating temporal control on performance but not placement. In contrast, exposure to 'placement' training resulted in 'placement' control but not temporal control. Full training (i.e. training on both tasks) resulted in both temporal and placement control. The results indicated novel instructional control as responding to these sequences had not been previously reinforced.

Hayes and Hayes (1989) proposed that instructions exhibited behavioural control through their participation in equivalence relations between stimuli, actual events, and associated relational cues. The instruction used in this study was "When the bell rings, go to the oven and get the cake". This is understood in terms of the relations between the physical stimuli 'Bell', 'Oven and 'Cake', the temporal relational cue of 'before' (i.e., Bell 'before' Oven 'before' Cake), and the actions involved (i.e., 'get', 'go'). Responding in accordance with the above rule requires following the correct sequence of actions, deriving the appropriate temporal relation between them. One particularly interesting aspect of this study concerns the potential reversibility of the sequence. The formal properties of the instruction

could be changed by employing an ‘after’ cue (e.g., Cake ‘after’ Oven, Oven ‘before’ Cake), fitting with the potential bidirectional structures rules can exhibit.

The Hayes and Hayes (1989) account of instructional control was the first to explicitly the address the complexity of temporal structure that instructions can establish. Without Before/After relational responding, it was not clear how humans can specify intricate sequences for each other, even though this is a very common feature of instructions. Subsequently, O’Hora and colleagues were first to empirically demonstrate derived before/after responding, in their work on instructional control (O’Hora, Barnes-Holmes, Roche, & Smeets, 2004). In Experiment 1, three participants were trained and tested to respond in accordance with ‘Before’, ‘After’, ‘Same’ and ‘Different’ relations in the presence of arbitrary stimuli. In testing, these relational stimuli were presented with numerous sets of novel stimuli and participants responded in accordance with numerous derived sequences of responses.

The current study investigated the effects of Before and After instruction on the speed of sequential responding. A number of researchers have explored the speed and flexibility of relational responding proposed by Hayes and Hayes to underlie instructional control. For example, Steele and Hayes (1991) measured response latencies for combinatorially entailed relations of ‘Same’ and ‘Opposite’. The results indicated that response latencies for ‘Same’ relations were lower than for ‘Opposite’ relations, with the authors concluding that the reason for the differences resulted from a more complex derived relation. In ‘Opposite’ relations, A-B and B-C result in the derived entailed relation ‘C is the same as A’, which differs to the trained ‘Opposite’ relation. In ‘Same’ relations, A-B, B-C entails ‘C is the same as A’, which requires the same relation as was trained.

A similar study (O’ Hora, Barnes-Holmes, Roche & Smeets, 2002) explored response latency times for particular relations that exhibit the property of mutual entailment (see

Hayes, Barnes-Holmes & Roche, 2001). Under this relational property, when a stimulus 'A' is related to a stimulus 'B' in some way, it can be derived that the relationship between 'B' and 'A' is mutually entailed. If, for example, the relation 'A' is *more than* 'B' is trained, then it can be derived that 'B' is *less than* 'A'. O'Hora et al predicted that, since the *less than* relation mutually entailed following a trained *more than* relation is a different relation than that trained, mutually entailed responses would be slower in the "more than/less than" condition than the "same as" condition. Their rationale, following Steele and Hayes (1991), was that mutually entailing a different relation than that trained constituted a more complex relational performance; that is, a behavior that required longer and more varied training (in terms of the environmental conditions required as antecedents and consequences) to be established and maintained. Latencies of derived relational responses in the more complex case, More than/Less than, were significantly greater than those of derived Same/Opposite responses. Both Steele & Hayes (1991) and O' Hora et al. (2002) demonstrate the usefulness of measuring response latencies for such responding, as differences in the relative time taken for responding to these relations were found.

Hyland, O'Hora, Leslie and Smyth (2012) examined latency of temporal relational responding. In this study, participants observed two-stimulus sequences of stimuli and were required to choose stimuli to complete either 'before' or 'after' statements describing the sequence. For example, having seen a circle followed by a square, participants were either required to choose a circle followed by a square in the presence of a 'before' cue, or a square followed by a circle in the presence of an 'after' cue. 'After' statements required participants to respond in reverse order to the presented sequence, similar to mutually entailed relations investigated by Steele and Hayes (1992) and O' Hora et al. (2002). Hyland et al found that 'before' statements were significantly faster than 'after' statements, providing further support responding in accordance with more complex relations takes longer.

Hyland et al. (2012) demonstrated that 'after' statements describing stimulus sequences were slower than 'before' statements. The current study examined the speed and accuracy of responding in accordance with 'before' and 'after' *instructions*. From a RFT perspective (e.g., Hayes & Hayes, (1989), responding in accordance with an 'A after B' instruction requires mutual entailment of the temporal relation in order for the participant to respond in the correct order, but an 'A after B' does not. In line with previous finding (Steele & Hayes, 1991, O'Hora et al, 2002, Hyland et al 2012), it was expected that responding to 'After' instructions would be slower than for 'Before'.

## Method

### Participants

Twenty-four participants from the National University of Ireland, Galway and Dublin Business School volunteered to take part in the current experiment (12 male and 12 female). Recruitment was conducted through email notification. Participants spoke English as their first language. An information sheet was provided to all participants with a number of criteria for participation in the experiment (e.g., language impairment). Full written informed consent was received by participants. All participants were required to indicate to the experimenter whether they could take part in the experiment based on the criteria on the sheet, without having to give a reason. All participants were naive to the subject area and had not taken part in any similar experiments. At the beginning of the experiment, all participants were randomly assigned to one of two training sequences, Before-After (BA) or After-Before (AB).

### Materials and Apparatus.

Participants were seated at computer desks in small laboratory cubicles. Simple geometric shapes were employed as stimuli (Circle, Square, Triangle, and Cross). Stimuli presented in the sequential instruction at the beginning of each trial were 4cm² in area, with

stimuli presented in the judgement stage of the trial also 4cm² in area. Shapes were controlled for identical length and width using the program Irfanview (Skiljan, 2007). The English words 'BEFORE' and 'AFTER' were used as cues and presented in the instruction. These cues were capitalised, black in colour and set at Times New Roman 24 point bold font. The program used was coded in Visual Basic Version 6 (Microsoft, 1998), and was run on a Packard Bell Personal Computer. The experiment was presented on a 15 inch CRT monitor. Prior to choosing the requested sequence in each trial, a message box was presented (see Figure 2). This message box in each trial was gray in colour, 3cm² in area, and the words "Click Here" were written in black Times New Roman 12 point font. During training, verbal visual feedback was provided; the word "Correct" was presented in green, or "Wrong" in red. Feedback was set at Times New Roman 18 point font.

**Procedure.**

All participants were exposed to a five-phase sequential responding task (see Figure 1). These phases included Before Training, Before Probes, After Training, After Probes, and Mixed Probes. In order to control for facilitation effects of exposure to one of the relational cues before the next, the sequence of training on Before and After was counterbalanced across participants. Twelve participants took part in the Before-After sequence: Before Training, Before Probes, After Training, After Probes, and Mixed Probes. The remaining twelve were exposed to the After-Before sequence: After Training, After Probes, Before Training, Before Probes, and Mixed Probes. The experimental procedure is outlined in Figure 1. There were 24 trial types in the final phase, Mixed Probes: each permutation of shapes in the observed relational statement was presented once in a quasi-random order (e.g., 'Circle' BEFORE 'Square', 'Triangle' AFTER 'Cross').

**[INSERT FIGURE 1 ABOUT HERE]**

Before Training

The instructions below were presented to each participant at the beginning of the Before Training and After Training phase. They were presented in the centre of the computer screen on a white background in Times New Roman size 22 bold font.

> This Training Phase requires you to concentrate on a set of 2 shapes at the bottom of the screen, related to each other in some way by a word in the middle. A second after the statement appears, a message box will appear above it. You are required to click on this message box. When you do, the statement will disappear and 4 shapes will appear at the top of the screen. You are required to click on the shapes that correspond to what you saw in the statement beforehand. The word relating the two shapes together may also have an effect on the order you choose each shape. Although only one word will be used to relate the shapes at any one time, these words may change during the study. It is therefore important to concentrate at all times. As in reading or writing, you must always respond from left to right in each trial. In the first stage, you will be provided with feedback. When you're ready, click the message box below. Good Luck!

At the start of a typical Before Training trial, a simple sequential instruction containing two shapes and a relational cue was presented at the bottom of a white screen below a black line (see Figure 2). Following a 1000ms interval, a grey message box with the words “Click Here” appeared in the centre of the screen above the black line. When participants clicked on the message box with the mouse, the instruction and message box disappeared and four shapes were presented equidistant from the message box location one above, one below, one to the left, and one to the right (see Figure 3). Clicking the message box ensured that prior to choosing the first shape; the mouse cursor was equidistant from all four shapes on the new screen. Participants were required to choose two of the four shapes in a particular order,

depending on the sequential instruction (e.g., ‘Circle’ BEFORE ‘Square’ required participants to choose ‘Circle’ followed by ‘Square’). Feedback in the form of a ‘Correct’ was presented in green colour and in size 22 Times New Roman font. Incorrect responding resulted in the word ‘Wrong’ appearing in a red colour in the centre of the screen, in size 22 Times New Roman font. Following completion of a trial, the screen cleared for a 1000 ms inter trial interval (ITI) before the next trial was presented.

Mastery criterion was set at 11 correct responses from 12 trials. Failure to reach criterion resulted in retraining on the respective training phase. Once criterion was met in Before Training, participants progressed to the Before Probes phase (see Figure 1).

Before Probes

The following instructions were presented to participants at the beginning of the Before Probes phase.

> This Phase is similar to Phase 1, except this is a testing phase and no feedback will be given after each trial. When you are ready, click on the box below.

Trials in the Before Probes phase were identical to Before Training except no feedback was given. The mastery criterion was set at 11 correct responses out of 12 trials. Participants who failed to reach criterion on this phase were retrained on Before Training.

After Training

Half the participants were exposed to After training first. For those participants in the BA sequence, demonstrating responding at criterion level on Before Probes resulted in progression to After Training. The following instructions were presented to all participants at the beginning of the third phase.

> This Phase is another training Phase. Remember to continue concentrating on the shapes and the word relating them together. Feedback will be provided in this Phase. When you are ready, click on the box below.

After training was similar to Before Training except that the cue 'AFTER' was used in the sequential instructions instead of 'BEFORE'. As in Before Training, there were 12 trial types, each of which was presented once in a quasi-random order. In this phase, participants were required to choose stimuli in accordance with an 'A AFTER B' instruction. For example, given the relational instruction 'Circle AFTER Square' participants were required to choose 'Square' followed by 'Circle' in that order. This resulted in 'Correct' feedback. Incorrect responding resulted in 'Wrong' feedback. The mastery criterion was 11 correct responses out of 12 trials. Demonstrating responding at criterion level resulted in progression to the After Probes phase, with failure resulting in retraining on After Training.

### After Probes

The instructions for the After Probes phase were identical to instructions for Before Probes, and this phase was procedurally identical to the After Training phase apart from an absence of feedback. Participants who reached criterion level progressed to Phase 5, with failure resulting in Phase 3 retraining.

### Mixed Probes

Instructions for Phase 5 were presented to participants upon completion of Phase 4. Phase 5 instructions were presented as follows.

> This is the final Phase of the Experiment, and is a little longer than the previous stages. This is another testing Phase and no feedback will be provided.

When you're ready, click on the button below.

**[INSERT FIGURE 2 ABOUT HERE]**

In the Mixed Testing Phase participants were required to respond to instructions containing both 'Before' and 'After' temporal relational cues. There were 24 trial types in this phase which were a combination of trial types from Phase 1 and Phase 3. Feedback was not presented in this phase. Mastery criterion was set at 21 correct responses from 24 trials. If participants failed phase 5, they were further exposed to this phase until mastery criterion was met. Only participants that reached mastery criterion on the first exposure were used for response speed analysis. On completion of the experiment, the following message was displayed for participants, followed by a full debriefing.

> Thank you very much for participating in this experiment. Without your help, we would not be able to conduct our investigations into the basic processes of language. If you would like to know more about this experiment or our ongoing research, please ask the experimenter and we will be glad to provide you with any information we can.

## Results

The raw data consisted of accuracy scores for all participants in each of the five experimental phases, and reaction time scores in the form of response speeds only for the final mixed phase. All participants completed the experiment. Pre-experimentally 12 participants were randomly assigned to the Before-After (BA) group and 12 were assigned to the After-Before (AB). Accuracy was very high, and only descriptive statistics were performed on accuracy data. Only correct responses were included in response speed analyses. Reaction time for the first response of the sequence was calculated from the point at

which the participant observed the instruction until the first comparison stimulus in the array was clicked. The reason for choosing these parameters to measure response time was to control for participants reversing the order of the instruction in advance of choosing the first comparison stimulus. Moreover, it may be argued that the respondent has decided the corresponding sequence of the instruction by the first comparison stimulus click. Inter-response duration, the time between choosing the first comparison stimulus in the sequence outlined by the instruction to the second comparison, was also measured. Several timings were measured for the purpose of analysing response speeds. Before/After response speeds were based on timings from the presentation of the instruction to choosing the first comparison stimulus in the array. This consisted of time measurement from the presentation of the instruction, through the initiation (clicking grey message box) to the first comparison response, where the timer was stopped. The inter-response speeds consisted from the time of the first comparison stimulus click to the second comparison stimulus click, where the timer was stopped. Response speeds were calculated as the reciprocal of the reaction time in seconds (See Hall, Sekuler, & Cushman, 1969, for overview on calculating response speed). Scores were compared for each participant in terms of relational cue employed, and across participants within and across BA and AB groups.

**Accuracy Data**

Accuracy data for all five stages are presented in Table 1. All 24 participants completed the experiment. Participants in the BA group progressed through phases in the order of Phase 1, 2, 3, 4, 5, with participants in the AB group progressing in the Phase order 3, 4, 1, 2, and 5. Twelve participants completed all phases on first exposure (7 in BA group, 5 in AB group). An additional seven participants passed Phase 1 within one extra training block (2 in BA group, 5 in AB group) and all of these participants subsequently completed all

further phases of the experiment without additional blocks required. A further two participants (BA group) required two additional exposures to Phase 1, and completed all further phases on the first exposure. Twenty three participants passed the Phase 2 probe at the first attempt. One participant (AB group), who required two training exposures on Phase 1 before reaching mastery criterion, failed Phase 2 on the first exposure and was retrained on Phase 1. This participant passed both Phases 1 and 2 following re-exposure to both phases.

**[INSERT TABLE 1 ABOUT HERE]**

Apart from the 12 participants who passed all phases at the first exposure, an additional 11 participants passed Phase 3 on the first attempt (4 in BA group, 7 in AB group). The remaining participant (BA group) required two additional exposures to reach criterion on Phase 3. All participants demonstrated responding at criterion level in Phase 4 probes. Twenty two of the 24 participants passed the final probe phase, Phase 5, within one exposure. Participant 8 in the BA group and participant 10 in the AB group required one additional exposure to Phase 5 before reaching criterion level. Both demonstrated correct responding above chance level on the first attempt, but did not reach mastery level. Both these participants were excluded from further analyses.

**[INSERT TABLE 2 ABOUT HERE]**

**Response Time Data**

Response speed analyses focused primarily on the speed of the first sequence response produced by the participant. Phase 5 response speeds were analyzed for 22 participants, with both Participant 8 in the BA group and Participant 10 in the AB group omitted because they failed to reach mastery criterion on first exposure to this phase. Mean response speeds were calculated for all correct ‘Before’ probes (combination of ‘Before’ probes for both the BA and AB response conditions), (M =0.278, SD = 0.032) and correct

'After' probes (combination of 'After' probes for both the BA and AB response conditions) (M = 0.274, SD = 0.03). These mean 'Before' probes corresponded to latencies of 3.6 seconds and 'After' probes to latencies of 3.65 seconds

**[INSERT TABLE 3 ABOUT HERE]**

**Statistical Analysis**

A 2 x 2 mixed Analysis of Variance (ANOVA) examined the differences between the within participants factor of response type (Before/After) and the between participants factor of response order (BA/AB group) in terms of speed of responding on the final Mixed Phase. A statistically significant difference in response type was found $F(1,20) = 3.01$, $p < 0.05$, partial $\eta^2 = 0.13$; participants responded to relational statements containing 'Before' cues significantly more quickly than 'After' cues. No differences were found between training order $F(1,20) = 0.54$, $p = 0.24$. There was also no interaction effect $F(1,20) = 0.00$, $p = 0.49$.

A second 2 x 2 mixed Analysis of Variance (ANOVA) examined the differences between inter-response speeds between Before/After instructions and response order in the final Mixed Phase. One might expect that choosing the second sequence stimulus would be faster in a Before probe because the second stimulus is in the same sequential order as observed in the instruction. Furthermore, one may expect faster responding in inter response speeds for Before probes due to earlier exposure to the first stimulus in the instruction. However, no differences were observed between response types, $F(1,20) = 1.22$, $p = 0.141$. There were also no differences found between training order $F(1,20) = 0.21$, $p = 0.33$ and no interaction effect $F(1,20) = 0.1$, $p = 0.379$.

A Pearson's correlation was conducted between response latency and trial number to determine whether there was an effect of learning in responding to relational statements over

time. A significant increase or decrease would suggest that responding was predicted by the position of trials. In the BA Group, there was a statistically significant negative correlation between response latency and trial number for Participant 5 ($r = -.638$, $p = .001$). This indicates that the participant responded more slowly over time in Phase 5. The absence of significant positive correlations between latency and trial number means that no participant got faster over time and suggests no effect of learning over time within the final phase. That is, training served to ensure that participants were responding accurately and at a stable speed prior to the critical test. In the AB group, there was a statistically significant negative correlation between response latency and trial number for Participant 6 ($r = -.507$, $p = .011$) and a significant positive correlation for Participant 10 ($r = .440$, $p = .031$). The latter positive correlation would suggest that Participant 10 exhibited an effect of learning over trials on Phase 5. Participant 10 in the AB group was one of the two participants who failed the final phase, which may have affected the outcome of the correlations. As this was the only participant who demonstrated such learning over time, it was assumed that response speeds generally did not change over time in the final phase.

To summarise, results indicated that responding was significantly faster in the presence of instructions containing 'Before' cues than for 'After'. No differences were observed for inter-response speed across both cues. Accuracy was consistently high across all five phases in the current study, regardless of the order in which participants were exposed to 'Before' and 'After' training. Moreover, Correlations further indicated that there were no learning effects during Phase 5.

**Discussion**

The current experiment provided the first known behavioural analytic attempt to explore the specific differences in responding to sequential instructions containing either

'Before' or 'After' relational cues. Participants were required to produce sequences of stimuli which corresponded to the instruction. Response speeds were measured between presentation of the relational instruction and production of the comparison judgements. High accuracy scores in all five phases and similar response speeds for both relational instruction types suggested that there were no differences between 'Before' and 'After' instructions on sequence production. The current study supported previous research on increased latency of complex mutually entailed relations. In accordance with this perspective, differences between temporal relational cue type would be expected, and may indicate differences in the strategy employed in responding to such verbal relational statements.

In probe Phases 2 and 4, most participants reached mastery criterion on first exposure, with only one participant requiring an additional training block to reach criterion level on Phase 2. In Phase 5, mixed probes, participants were exposed to random probes containing either 'Before' or 'After' instructions. Only two of the 24 participants required an additional exposure to reach mastery criterion, notwithstanding the fact that responding was at greater than chance level for both participants on first exposure. In the present study, the only difference between the instructions and subsequent stimuli was the relational cue employed in the instruction, which would suggest that the magnitude of the response was identical. There were differences between the relational cues, even though according to this view the complexity and length of the planned action (e.g., Hull 1932) (i.e., responding to the instruction) were identical for both conditions.

The current study was designed to analyse sequential responding to temporal instructions containing either 'Before' or 'After' relational cues. Support is provided for previous findings that responding to particular instructions is affected by the relational cue contained in the instruction, rather than the order in which the shapes are presented. These data also support the assertion that it takes longer to respond in accordance with more

complex entailed relations (Hyland et al., 2012; O'Hora et al., 2002; Steele & Hayes, 1991). In the current experiment, it was predicted that responding to 'After' instructions would result in slower response speeds, as participants were required to derive the mutually entailed 'Before' relation when choosing stimuli. Such differences were evident between response speeds for 'A before B' instructions which occasioned forward responding (i.e., Choose A...B) and 'A after B' instructions which occasioned reverse responding (i.e., Choose B...A).

Functional accounts of relational responding, such as RFT, posit that features of behavioral history explain such responding. In the current study, increased response latencies (slower response speeds) were observed when successful performance (e.g., choosing B first, then A) constituted mutual entailment of the relation in the instruction provided (e.g., "A after B"). In line with this functional account, it is likely that increased practice on After instructions will reduce the difference in latencies relative to responding to Before instructions. Indeed, the extent to which response latencies to After instructions can be reduced warrants further study. It is worth remembering, however, that the participants in the current study were highly verbal college students and they were reliably highly accurate on After instructions, so reductions in the response latency difference may not occur.

Previous research by Clark (1971) found that children learn the 'before' temporal relation first in early language development, as this relation coordinates with the order of the stimuli. In the statement 'A before B', participants may utilise the coordination relation between stimuli (If 'A before B' then stimulus 'A' is chosen first, followed by stimulus 'B'). It would be expected that employing this strategy to understand the verbal instructions would result in faster responding to 'before' statements, which was supported by the present study. The findings are in contrast to views that participants may respond more readily in accordance with the absolute properties of the stimuli. For example, Beaman and Morton (2000) found that sequences of stimuli which occur at the very end of a stimulus list, but

recalled at the beginning of the response task, produce a recency effect. They reported that out of the sixteen cases where sequences were recalled that involved the terminal stimulus (the last in the list), 50% involved only one preceding stimulus (i.e. stimuli 15 and 16). Memory for sequential information relating stimuli together seemed to vanish once recall began. Quite important for future research, it was found in the Beaman and Morton study that free recall of sequentially related visual stimuli containing more than two related constituents causes increased cognitive difficulty due to the complexity of the relation (Andrews & Halford, 2002). In line with the findings of the present study, a stronger before/after effect may be exhibited if more than two arguments are incorporated (e.g., Andrews & Halford, 2002). However, it may also be the case that the complexity of the instruction may equalise the before/after effect. Little research if any has been conducted examining temporal relational complexity, which necessitates further investigation. Future research may also attempt to explore further the strategies used when responding to sequences of stimuli, and whether there are differences in the modalities (e.g., Visual and Auditory) in memory for such responding.

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Figure Captions

Figure 1. An outline of participant progression in the current Experiment. Phases 1 to 4 required participants to respond to temporal relational instructions by choosing the corresponding comparison stimuli in a particular sequential order. The above Figure outlines phase progression in the Before-After group. In the After-Before Group, participants progressed in the following phase order; Phases 3, 4, 1, 2, 5. Phase 5 involved observations of both types of temporal relational instruction.

Figure 2. An outline of a trial in the current Experiment. Screen A illustrates the presentation of the relational instruction below a black line. In screen B, a message box appeared on the screen 1000 ms after the instruction appeared on the screen. In screen C, choosing the 'Circle' first, followed by the 'Square', resulted in correct feedback, which is illustrated in screen D.

Figure 1

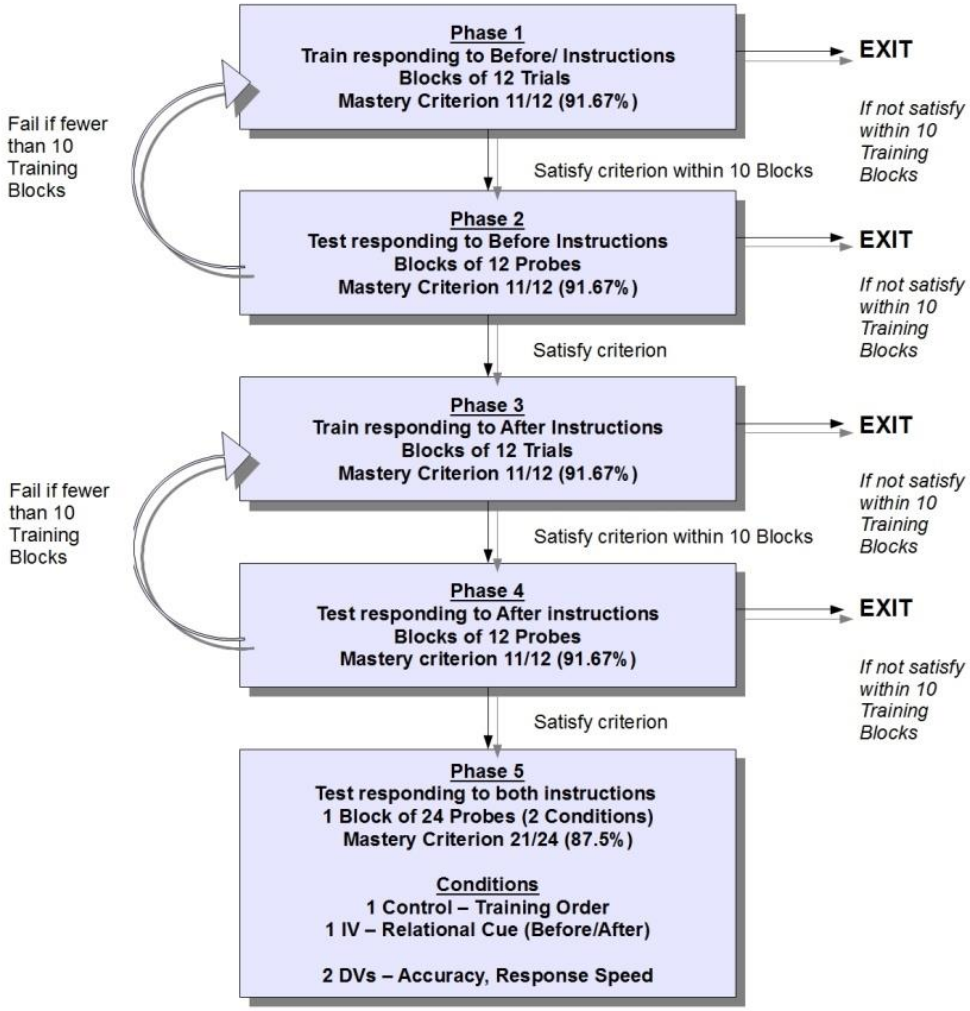
Phase 1
Train responding to Before/ Instructions
Blocks of 12 Trials
Mastery Criterion 11/12 (91.67%)
EXIT
If not satisfy within 10 Training Blocks
Fail if fewer than 10 Training Blocks
Satisfy criterion within 10 Blocks
Phase 2
Test responding to Before Instructions
Blocks of 12 Probes
Mastery Criterion 11/12 (91.67%)
EXIT
If not satisfy within 10 Training Blocks
Satisfy criterion
Phase 3
Train responding to After Instructions
Blocks of 12 Trials
Mastery Criterion 11/12 (91.67%)
EXIT
If not satisfy within 10 Training Blocks
Fail if fewer than 10 Training Blocks
Satisfy criterion within 10 Blocks
Phase 4
Test responding to After instructions
Blocks of 12 Probes
Mastery criterion 11/12 (91.67%)
EXIT
If not satisfy within 10 Training Blocks
Satisfy criterion
Phase 5
Test responding to both instructions
1 Block of 24 Probes (2 Conditions)
Mastery Criterion 21/24 (87.5%)
Conditions
1 Control – Training Order
1 IV – Relational Cue (Before/After)
2 DVs – Accuracy, Response Speed

Figure 2

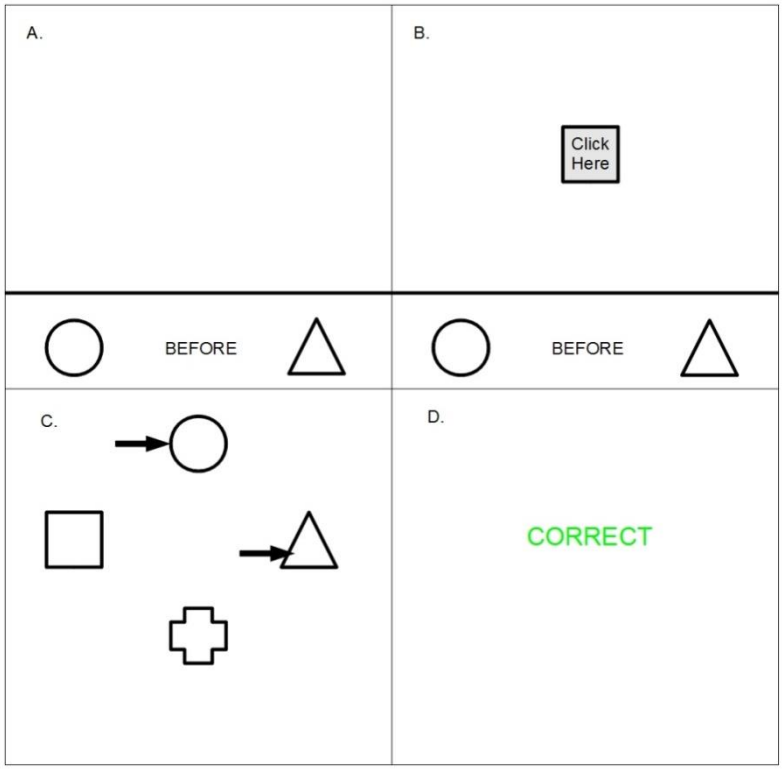

**Table 1.** *Number of Trials Completed by BA Group Participants in Each Phase Before Criterion Was Met.*

| | Phase 1<br>Bef. Train | Phase 2<br>Bef. Probes | Phase 3<br>Aft. Train | Phase 4<br>Aft. Probes | Phase 5<br>Mixed Probes |
|---|---|---|---|---|---|
| P1 | 12/12 | 12/12 | 12/12 | 12/12 | 24/24 |
| P2 | 12/12 | 12/12 | 11/12 | 12/12 | 24/24 |
| P3 | 12/12 | 12/12 | 11/12 | 12/12 | 23/24 |
| P4 | 12/12 | 12/12 | 12/12 | 12/12 | 23/24 |
| P5 | 32/36 | 12/12 | 11/12 | 12/12 | 24/24 |
| P6 | 11/12 | 12/12 | 12/12 | 12/12 | 23/24 |
| P7 | 21/24 | 12/12 | 12/12 | 11/12 | 24/24 |
| P8+ | 12/12 | 12/12 | 32/36 | 12/12 | 40/48 |
| P9 | 32/36 | 12/12 | 12/12 | 11/12 | 24/24 |
| P10 | 11/12 | 12/12 | 12/12 | 12/12 | 24/24 |
| P11 | 22/24 | 12/12 | 12/12 | 12/12 | 21/24 |
| P12 | 12/12 | 12/12 | 12/12 | 12/12 | 24/24 |

*Note*. The first figure in each cell refers to the number of correct trials and the second number refers to the total number of trials completed. Blocks for Before Training, Before Probes, After Training, and After Probes all consisted of 12 trials per block. Mixed Probes blocks consisted of 24 trials. Participant 8 is marked with a plus symbol, with this participant requiring additional exposure before reaching criterion level.

**Table 2.** *Number of Trials Completed by AB Group Participants in Each Phase Before Criterion Was Met.*

| | Phase 3 Aft. Train | Phase 4 Aft. Probes | Phase 1 Bef. Train | Phase 2 Bef. Probes | Phase 5 Mixed Probes |
|---|---|---|---|---|---|
| P1 | 12/12 | 12/12 | 12/12 | 12/12 | 24/24 |
| P2 | 18/24 | 12/12 | 11/12 | 12/12 | 24/24 |
| P3 | 34/36 | 22/24 | 11/12 | 12/12 | 23/24 |
| P4 | 12/12 | 12/12 | 12/12 | 12/12 | 23/24 |
| P5 | 19/24 | 12/12 | 11/12 | 12/12 | 24/24 |
| P6 | 12/12 | 12/12 | 12/12 | 12/12 | 23/24 |
| P7 | 21/24 | 12/12 | 12/12 | 11/12 | 24/24 |
| P8 | 11/12 | 12/12 | 32/36 | 12/12 | 24/24 |
| P9 | 11/12 | 12/12 | 12/12 | 11/12 | 24/24 |
| P10+ | 11/12 | 12/12 | 12/12 | 12/12 | 42/48 |
| P11 | 22/24 | 12/12 | 12/12 | 12/12 | 21/24 |
| P12 | 20/24 | 12/12 | 12/12 | 12/12 | 24/24 |

*Note*. The first figure in each cell refers to the number of correct trials and the second number refers to the total number of trials completed. Blocks for Before Training, Before Probes, After Training, and After Probes all consisted of 12 trials per block. Mixed Probes blocks consisted of 24 trials. Participant 10 required an additional exposure to Phase 5 before reaching criterion level. Participant 3 was the only participant who failed Phase 2 and was rexposed to Phases 1 and 2.

**Table 3. Descriptive statistics for both groups (times in seconds).**

| Response Group | Response Type | M | SD |
|---|---|---|---|
| Before-After | Before | 0.283 | 0.035 |
| | After | 0.279 | 0.031 |
| After-Before | Before | 0.274 | 0.029 |
| | After | 0.269 | 0.031 |

**Note. Participant 8 in the BA condition and participant 10 in the AB condition were not included in the analysis, due to these participants not reaching mastery criterion.**