Unconscious priming dissociates 'free choice' from 'spontaneous urge' responses

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ABSTRACT

Advances in neuroscience offer the exciting prospect of understanding 'free' choices – the subject of the free will debate in philosophy. However, while physiological techniques and analysis have progressed rapidly to meet this challenge, task design has not. The challenge is now to develop laboratory tasks that adequately capture 'free' picking or choosing. To isolate 'internally' generated intentions from those impelled by external stimulus, observers are asked to 'choose freely' or to wait for a felt 'urge'. However, no previous work has explicitly distinguished between instructions that refer to 'urges' versus to 'choosing'. The philosopher Alfred Mele (e.g., 2009; 2014) has argued that the distinction is of crucial conceptual importance, but the two have not yet been empirically distinguished. Here, we show that conscious and unconscious, task-irrelevant primes, bias observers' binary choices when they are instructed to 'choose freely', not when they 'wait for an urge', underscoring the practical importance of Mele's conceptual distinction. Neuroscience must incorporate this distinction if we are to understand processes underpinning free choice.

(167 words)

Key words: Free choice, Urge, Negative Compatibility Effect, Unconscious priming.

Highlights:

- Since the 1980's, neuroscience has addressed philosophical debates around 'free will'.
- Previous work instructed observers to respond on the basis of a 'free choice' or a felt 'urge', but did not distinguish between these two instructions.
- We show that unconsciously-perceived prime stimuli *selectively* influence responses made on the basis of a free choice, but not of a felt urge.
- This dissociation of the two instructions underscore the importance of distinguishing free choosing, or picking, from urge-based responses

1. INTRODUCTION

Human decision-making is accompanied by a compelling, subjective sense of being able to do otherwise: that our choices are not exhaustively determined by the reasons we cite for them, but rather are 'up to us' (e.g., Searle, 2001; Haggard, 2008; Griffith, 2005; 2010). The philosophical problem of 'free will' is a debate, rooted in antiquity, about how such subjective freedom is best reconciled with our understanding of human agents as physical systems – how our decisions are related to their non-conscious antecedents and, separately, in what sense the brain's conscious processes hold authorship of our choices. In philosophy, libertarian views hold that choices are not exhaustively pre-determined by their psychological- or physiological- antecedents (e.g., Kane, 1998; Searle, 2001b; Clarke, 2006; Tse, 2013). Conversely, most modern perspectives assume that choices *are* predetermined and that this is either *compatible* with choices being in some senses 'free' and 'up to us' (Dennett, 1984, Frankfurt, 1969; Holton, 2006; 2009) or the two claims are *incompatible* and our choices are not free (e.g., Honderich, 1988; Wegner, 2002, Harris, 2012; Pereboom, 2001). Philosophy has articulated the limitations of each view, but a firm resolution will require measurement of those brain processes responsible for choice.

For more than 30 years, to address this debate, neuroimaging and stimulation techniques have been exploited to predict, and to manipulate, choices. The essential logic of those studies was that if physiological measures could be used to predict (or to control) which choice a person would make, before they themselves reported being aware of making the choice, their choice would likely have been pre-determined, contrary to libertarian views. Moreover, if it could be demonstrated that processing *akin to intention* could be measured prior to conscious intention emerging, this may undermine the association of intentional-action and conscious awareness.

Libet's pioneering experiments used readiness potentials (Bereitschaftspotentials, BPs; Kornhuber & Deecke, 1965; a slowly rising signature in EEG preceding voluntary movement) to predict *when* observers would choose to make a button-press with their index finger (e.g., Libet, Gleason, Wright, & Pearl, 1983; Libet, 1985). In those studies, the instructions to observers made reference to letting 'the *urge* [our italics] to act appear on its own at any time without any preplanning or concentration on when to act'. Subjects were also asked to note the earliest awareness of the specific *urge or intention* to act, and to note the 'clock' position of a dot travelling in a circular path at 1 rotation every 2.5 seconds. The RP began around 350 ms prior to the estimated time of conscious awareness of the *urge, wish*, or decision to move, prompting Libet to suggest that, contrary to lay understanding of conscious free-will, the urge or choice to move had been determined by unconscious processes prior to the apparent moment of conscious choice.

While initial reaction to Libet's work was mixed, those tasks were a pioneering attempt to target internally generated responses in a task, rather than those elicited and controlled by external stimulus. Only *internally* generated responses could satisfy the requirement (for addressing 'free will') of unambiguously being 'up to' the observer. Self-evidently, the *general* type and timing of choices in the laboratory will never be free of task demands - the experimenters clearly want observers to make *some* responses during the session, and for responses to be of a very particular kind (index-finger button presses). However, the *specifics* of observers' responses in the task (the timing, and in later examples, the nature specific response) *were* effectively up to the observer.

Following Libet's example, subsequent work has predicted of observers' choices made on the basis of *urges*. For example, Soon, Brass, Heinze, and Haynes, (2008) used fMRI to predict 'free' decisions in a freely paced motor-decision task; observers were asked, when they felt the urge to do so, to freely choose between pressing one of two buttons with their left or their right index fingers. Brain activity of prefrontal and parietal cortex encoded which button would be pressed by up to 10 s before their estimate of observers' reported conscious decision (see also, Bode et al., 2011). This method was subsequently extended by Soon, He, Bode, and Haynes, (2013) to more abstract choices. Observers chose either to add or to subtract numbers *when they felt the urge* to do so.

There is also compelling evidence for a causal role of particular brain areas in generating either urges or free-choices. Fried et al., (1991) stimulated the supplementary motor area (SMA) in patients with intractable epilepsy, eliciting a subjective '*urge' to perform a movement*, or an '*anticipation'* that a movement was going to occur. Similar findings were obtained by Lim et al., (1994) and Desmurget et al., (2009); stimulation of posterior parietal cortex elicited spontaneous reports of "will," "desire," and "wanting to move".

As this brief review illustrates, there is substantial evidence that cortical activity predicts and influences *either* free choices or urges, or both of these. It has also become clear the distinguish responses on the basis of free-choice versus of felt urges; however, there has been no systematic effort, yet, to do so empirically (e.g., Mele, 2009; Roskies, 2010; Bayne, 2011). Exactly what observers understood by an 'urge' in free-choice paradigms has proven difficult to ascertain - perhaps a bodily sensation, perceptual correlates of a motor plan or of being 'about to move'. It is clear that an 'urge' to act, in everyday life, can be distinguished from forming an intention to act- someone who has quit smoking may feel a strong urge to smoke, but not decide to do so. However, in laboratory free-choice tasks that explicitly minimize stimulus-induced or bodily-state driven urges, this distinction becomes blurred. Perhaps, when a observer is asked to respond when they feel a *spontaneous* 'urge to do so', they interpret this as an instruction to make a spontaneous free choice of the type(s) that interest philosophers; perhaps not. Note, too, that this issue cannot be satisfactorily resolved by arguments about what observers understand by an 'urge'. Instead, only a clear *empirical* dissociation of the two tasks will suffice. If responses made under instructions to press one of two buttons when the observer 'feels an urge' to do so (an 'urge' instruction) were to differ markedly from those when the observer is asked simply to choose freely (a 'free choice' instruction), this would provide strong evidence that observers in previous studies had not processed urges in the same way as decisions. Here we report, to our knowledge, the first direct *objective* comparisons of responses made under urge and free-choice instructions, finding different effects of unconscious (or barely-perceptible) stimuli and conscious stimuli (in Experiment 3) upon performance in both of two experiments.

To anticipate our conclusions, the current experiments find clear behavioural evidence of a dissociation between responses when observers are instructed to make *free choices* to act versus when observers are instructed to act on the basis of felt *urges*. This dissociation is evident in the effect that task-irrelevant prime stimuli exert on behaviour. Previous reports suggested that such stimuli, even when unconsciously perceived, can influence volitional executive processes and responses when observers are asked to make free choices (Lau & Passingham, 2007; Kiesel, Wagener, Kunde, Hoffmann, Fallgatter, et al. 2006; Ansorge, Kunde, & Kiefer, 2014; Manly, Fish, Griffiths, Molenveld, Zhou, et al. 2014). Such findings presented an opportunity to compare the effects of unconsciously-perceived stimuli on responses made under urge versus free choice instructions. In the first experiment, we sought to establish associations between each of two unconsciously-perceived prime shapes and a left or right hand response, then to measure the effect of presenting these primes on responses when observers were asked either (i) to make a *free choice* as to which finger to press with, or (ii) to wait for an *urge* to press with either finger and then act upon it. We expected the masked prime shapes to affect processing in the free choice task, given previous results, but did not make a prediction for the effect under urge instructions. In brief, the first experiment was designed to create the conditions in which actions on the basis of urge-based versus free-choice instructions might be dissociated.

2 Experiment 1 – Simple Prime-Response Associations Established in Training Phase

As outlined above, our first study exploited a procedure employed by Zhou & Davis (2012) to establish stimulus-response associations between arbitrary, unconsciously-perceived prime shapes and left or right index-finger button presses. These associations have been found to influence subsequent free choices – if the associated prime is presented prior to an instruction to choose freely between a left or right button press. As such effects can be highly labile and vulnerable to differences in displays and timing, we first ran a pilot experiment to establish that such effects would arise using the procedure and apparatus used in Experiment 1. This is not reported in detail here, for brevity, but differed from Experiment 1 in that a prime shape was presented only ever once per trial. It yielded a significant influence on free choices in the direction reported by Zhou & Davis (2012): $t(16)=-2.905$, $p=0.011$. However, we suspected that this effect (a 2% bias in responses) would be too small to distinguish urge and free-choice conditions. We therefore conducted the experiment reported below, using the same paradigm but with repeated presentations of the prime stimulus (every 500 msec) during each trial of the test phase. Though we did not anticipate this, stronger unconscious stimulation in each trial due to repeated prime presentation gave rise to strong *negative-compatibility effects* (see *Results and Discussion* section) when observers were instructed to make free choices, but not when they were asked to respond on the basis of spontaneous urges.

2.1 METHOD

2.1.1 Observers

Forty-eight observers (24 in Experiment 1A: mean age 24.3, SD=4.3, 17 women, 24 in Experiment 1B: mean age 27.1, SD=6.5, 14 women) participated in Experiment 1 and gave informed written consent for their participation (power circa 0.8 for large effects in least powerful analyses). According to self-report, all but three observers were right-handed, and all had normal or corrected to normal vision and hearing. All observers received payment of £7. Two observers from Experiment 1A and 1 from Experiment 1B were excluded from group analyses due to responding with the same hand on more than 95% of occasions.

2.1.2 Apparatus and Procedure

The experiments were run on Dell PC with E-prime experiment generator software (Schneider, Eschman, & Zuccolotto, 2012) connected to a LS23A750DS/EN 23 inch LCD monitor, with brightness and contrast settings (60% and 75%, respectively) yielding approximate luminance values of 0.3 and 164 cdm^{-2} for black prime shapes and the white background, respectively.

Training Phase: The training phase consisted of one block of 200 trials (following 15 practice trials). Figure 1 schematises a typical display sequence within a trial, each of which began with a black central fixation cross, presented against a uniform white background. After 2000 msec, the fixation cross was replaced by a black prime shape appeared for 16 msec; on half the trials this was a diamond and the remaining trials, a square (each edge 37 mm). The prime then disappeared for 16 msec, after which a visual mask formed by the superimposed outlines of both the square and diamond was presented for 50 msec. The duration of the prime and masking were designed to render the primes consciously indistinguishable from one another. After the mask offset, a sequence of single uppercase letters (8 mm in height) was randomly generated and presented at fixation for 500 msec. Simultaneously with presentation of the second, third or fourth letter (randomly allocated in each trial) a verbal instruction “left” or “right” was played instructing the observer to press the left or right response key, respectively. Further letters were displayed in succession until the observer’s response was registered. The observer’s task involved, not only pressing the key indicated by the auditory instruction, but also remembering the letter that was on the screen *when they heard the auditory instruction*. The observer had then to select that letter in a “response-mapping” display of three letters and a hash symbol. Observers selected the remembered letter with one of the four response keys operated by index and middle fingers of their two hands. The keys corresponded to the position of the four symbols on the “response-mapping” display (illustrated in Figure 1). Although we were not particularly concerned with observer’s subjective timing of the auditory signal, this feature of the task served to separate the observer’s responses to minimize biasing effects of one response upon the next.

During the training phase, each particular prime shape (e.g., a diamond) was always presented prior to a particular auditory instruction (e.g., ‘left’). Hence, we expected that observers would come to associate each of two unconsciously-perceived prime shapes (diamond, square) with a particular response (left button press, right button press). The mapping of prime to response was consistent within an observer, but counterbalanced across observers.

Test Phase: The test phase consisted of one block of 100 trials. Each trial began with a black central fixation cross presented against a uniform white background for 5000 msec.

This long preparatory period was intended to help the observer minimise influences of previous choices on their current choice. The same stimulus sequences were presented as for the training task, except that no auditory instruction was presented and a masked-prime display was introduced in between each letter frame, i.e., every 500 msec (display sequence schematised in Figure 2). Observers were instructed to look at the letter stream and to press either the left or right key according to the following instructions. In Experiment 1A, the observers were instructed to make a 'free choice' on every trial between pressing the left or right response within a frame of 5 seconds, *not* to press on the basis of an 'urge' to respond and not to take into account any previous choices. In Experiment 1B, (other) observers were instructed to wait until they 'felt an urge' to press one button or the other and not to take into account any previous choices. In both experiments, if a response was not made after 5 seconds, the instruction "respond now" was presented, disappearing when the observer responded. As in the Training Phase, observers were also asked to remember the letter that was on the screen when they *made their free choice* (Experiment 1A) or *felt the conscious urge* (Experiment 1B) to press the button, and to select it from the response-mapping display. Observers' responses were coded in relation to the prime shape presented in each trial. If the response was the same response associated with the prime shape in the Training Phase, the response was coded as 'congruent', otherwise as "incongruent". Our primary measure was the proportion of congruent responses in each condition.

<u>Discrimination Task:</u> Finally, observers completed a 100-trials forced-choice diamond/square identification task in which the prime shapes were presented in random order. The structure of the trials was similar to that in the previous phases but after three letter presentations observers had to respond by pressing one of two keys (1 or 4 on the

numeric keypad to the right of the keyboard), without subsequent screen for the selection of the letter. The primes were presented in random order and the key response was counterbalanced across observers. A "beep" signalled an incorrect response, allowing observers to maximise their discrimination of the prime stimuli. After the discrimination task observers were asked whether they thought they could discriminate to assess their subjective awareness of the primes.

2.1.3 Procedure

The observers were tested individually in room under low illumination. They sat facing a computer screen at a comfortable viewing distance. Observers were given written task instructions, but not informed about the shapes of the primes that were presented. The observers each received written task instructions prior to the Training Phase Task and a separate set of instructions prior to the Test Phase Task. Finally, the observers were informed of the primes' shapes and were asked to perform the Discrimination Task.

2.2 RESULTS

Training Phase: Observer accuracy in performing the left/right response was 94.6% in average (94.6%, SD=3.2 for Expt. 1A; 94.6%, SD=5.6 for Expt. 1B). The mean accuracy for choosing the correct letter was only 62.2%, SD=36.2 for Experiment 1A and 77.7%, SD=26.3 for Experiment 1B. While these low means entirely reflected extremely low accuracy scores in 3 observers from Experiment 1A, it became clear that this was, for some observers, a challenging task whose accuracy we could not determine in the Test session. Accordingly, we elected not to analyse these subjective moments of choice/urge in the Test Phase (their purpose in these experiments, anyway, had been primarily to provide a task that separated the choice responses in the test phase).

Test Phase: We plotted the percentage Incongruent and Congruent responses for observers who performed the Test Phase with Free Choice Instructions (see Figure 3; Experiment 1A, left-hand axis, left pair of columns) versus with ‘Urge’ Instructions (Experiment 1B, left-hand axis, right pair of columns). Both Incongruent and Congruent were included so that each could be related to the mean RT for those trials, indicated on the same plot (right-hand axis). Visual inspection of the plot suggested that in Experiment 1A (Free-Choice Instructions), the percentage of observers’ choices that were congruent with the prime shape presented on the same trial (46.7%) differed from chance (50%); confirmed in a one-sample, two-tailed t-test (t(22)=2.92, p=0.008, *d*=0.53). This was not the case for Experiment 1B (Urge Instructions), in which the percentage of congruent responses was 49.6%, not significantly different from 50% (t(23)=0.39, ns). Comparing the relative bias in the two experiments, an unrelated t-test indicated that the bias in Experiment 1A differed marginally from that in Experiment 1B (t(43)=2.04, p=0.048 [1], *d*=0.29). Inter-observer means of mean RTs for Experiment 1A and 1B appeared, in the plot reproduced in Figure 3, to show shorter RTs for Experiment 1A than 1B (1634 and 2122 msec, respectively), but no influence of Prime Congruency. A two-way, mixed ANOVA, with factors of Experiment (1A, Free Choice Instructions versus 1B, Urge Instructions) and Prime Congruency (Congruent versus Incongruent) yielded a main effect of Experiment, F(1,23)=4.71, p=0.041, $\eta^2 p$ =0.17, but not main effect of Prime Congruency or any Interaction (both F’s<0.1, ns; neither experiment showed any effect individually, both F’s<1, ns).

To preclude the possibility that different Congruency effects on choices in Experiment 1A versus 1B reflected faster RTs in 1A than 1B, we equalised mean RTs in

[1] It transpired that these results were affected very slightly by our exclusion of observers who had responded with the same hand on nearly every trial; the whole sample showed the same pattern of results: t(24)=2.93, p=0.008 and t(24)=0.43, ns, for Exp1A and 1B respectively; interaction between Experiment and Congruency for the Response Bias, t(46)=1.97, p=0.054.

the two groups by removing faster observers in Experiment 1A and slower observers in Experiment 1B (4 of each), until mean RTs were equated in the two Experiments. Re-running the independent t-test comparing percentage Congruent responses in Experiment 1A vs 1B within this *matched* subset of RTs, revealed a significant difference between the effects in the two conditions, ($t(38)=-2.49$, $p=0.017$, $d=0.37$) despite the reduced sample size (see Figure 4). If anything, differences in RTs between Experiments 1A and 1B had greatly minimised, rather than exacerbated, the dissociation we noted here.

Finally, to preclude the possibility that longest RTs in responses (i.e. those responses made after the instruction of 'response now' was presented), were affecting in a different way free choices and urges, we filtered trials in which RTs were longer than 5820 msec (0.96% of trials for Expt. 1A and 2.37% of trials for Expt. 1B). Reanalysis showed the same pattern of results, for Expt. 1A ($t(22)=-2.80$, $p=0.011$, $d=0.51$), Expt. 1B ($t(23)=-0.13$, ns) and the different in Congruency effect between them, $t(43)=2.10$, $p=0.041$, $d=0.31$.

Prime discrimination: On the basis of binomial tests for each observer, accuracy of discrimination differed from chance for only one observer in each Experiment (p's=0.012 and 0.035, respectively). However, in Experiment 1A, on average, performance was below chance (mean=47.23%, SD=4.34, ($t(22)=-2.99$, $p=0.007$, $d=0.55$) and not for Experiment 1B (mean=50.65%, SD=5.48, $t(23)=0.57$, ns). This different discrimination performance in the two Experiments threatened our interpretation of Experiments 1A and 1B – raising the possibility that priming effects in Experiment 1A may have reflected marginal *conscious* perception of the prime shapes, rather than unconscious perception. To assess the likelihood of this possibility, we performed a Spearman's Rank correlation analysis between Prime Congruency and Accuracy of discrimination in Experiment 1A that showed no relationship between them, $r=-0.007$, $p=0.974$ (plotting the two also revealed no nonlinear pattern that might be missed by correlation). To further assess this possibility, we reanalysed Experiment 1A in terms of each observer's percentage of congruent choices, excluding 8 observers from analysis that showed the greater negative discrimination effect so that performance for the remaining observers was at chance ($t(16)=-0.54$, ns). If our effects in Experiment 1A had been due to marginal conscious perception in some observers, the congruency effect should not have been evident in those observers; however, it was ($t(16)=2.19$, $p=0.045$, $d=0.49$).

2.3 DISCUSSION

In Experiment 1A, when observers' were asked to make free choices, those responses were biased by external unconscious stimuli that had been associated with those responses in an earlier Training Phase. No such effect was evident when the responses were made according to an instruction to press when the observer felt an 'urge' to do so. The prime-congruence effect on free choices (Expt. 1A) was a Negative Compatibility Effect-like (NCE; Eimer & Schlaghecken, 1998) in which choice associated with a particular, unconsciously-perceived stimulus is made *less* often, or more *slowly* than other choices. Eimer and Schlaghecken (1998; Schlaghecken & Eimer, 2002) initially described the NCE in terms of differences in response times, but those authors (Schlaghecken & Eimer, 2004) have subsequently shown that the same effects can influence 'free choices'. While Schlaghecken and Eimer attributed the NCE to a 'self-inhibition' process (see also Sumner, 2008), other authors have claimed that the effect is perceptual in origin and due to *perceptual* interactions between prime and mask (Lleras & Enns, 2004; Verleger, Jaskowski, Aydemir, Lubbe, & Groen, 2004). Indeed, the unexpected visibility *below* threshold found in Experiment 1A might, in principle, have reflected such mask-induced activations (Lleras & Enns, 2004; Sumner, 2008) on perceptual decisions in the

Discrimination Task. However, though of interest, this debate is not key to our current discussion. Rather, our effects form part of a growing literature in which unconsciously-perceived stimuli appear to affect free choices (Parkinson & Haggard, 2014; Bodner & Mulji, 2010; Schlaghecken, Klapp & Maylor, 2009; Kiesel et al. 2006; Schlaghecken, & Eimer, 2004). What is new about the current work is that we distinguish clearly between responding on the basis of a 'free' choice versus on the basis of a 'spontaneous urge', finding an NCE in the former, but not the latter case.

Finally, one attractive feature of employing unconsciously-perceived prime stimuli in this first experiment was that they did not, it would seem, elicit responses effectively from observers in either the free choice or urge conditions. In this sense, the 'free' choices in Experiment 1A and the 'urges' that we hoped had prompted responses in Experiment 1B likely arose *relatively* spontaneously, without a major, immediate triggering influence of the prime stimulus. Such influences could have fundamentally changed the choices in our experiments and it was important to minimise them.

3. Experiment 2 – Effects of action observed unconsciously under dichoptic viewing

In Experiment 2, we sought to remedy some weaknesses in the design of Experiment 1. First, Experiment 1 had used a between-observers design that reduced its power. Secondly, the *time restriction* imposed in the task (observers had a maximum of 5 seconds to respond) may well have affected observers' responses, compelling them to set their internal threshold for deciding that they had 'felt an urge' very low so as to respond in time. We additionally wondered whether the abstract shapes employed in Experiment 1 and the simple stimulus-response associations we established in the Training Phase, may have been more suited to biasing free choices than to inducing 'urges' to move; the latter are more associated with activity in the supplementary motor area (SMA; Fried et al. 1991; Fried et al. 2011).

To these ends, Experiment 2 utilised dichoptic presentation to present short video sequences to the observer's non-dominant eye. The video clip showed a person (Author MTM) pressing one of the two response keys on the keyboard used in the experiment (Schematised in Figure 5 for a series of stills). We expected that observing the action in movie would elicit responses in SMA (see Caspers, Zilles, Laird, & Eickhoff, 2010; Chong, Williams, Cunnington, & Mattingley, 2008) and perhaps an 'urge' to move. To the other, dominant eye, a masking stimulus was presented simultaneously that was of sufficiently high-contrast as to render the movie presented to the non-dominant eye invisible (this effect is commonly referred to as 'Continuous Flash Suppression'; Tsuchiya & Koch, 2004). A further advantage of this new approach was that it required no Training Phase to establish an association between the priming stimuli (the video clips) and each response. Accordingly, each observer could perform both the 'Free Choice' and 'Urge' Conditions, making the comparison of these two conditions within-observers (run order counterbalanced across observers). To further streamline this procedure, we removed the sequence of letters used in Experiment 1 and any need to remember those letters (we also ran a version with those letters present – see *General Discussion*). This minimised attentional load, which has been shown to suppress coding of action observation. Instead, we asked observers on each trial to indicate, in the free-choice condition of this new experiment, how free they felt in making a free choice, and in the urge condition, how strong was the urge that prompted them to press the button. This task still, however, retained a useful feature of the letter-memory component in Experiment 1 – to minimise intertrial response dependencies in choices/urges by interleaving another task between each choice/urge response.

3.1 METHOD

3.1.1 Observers

Twenty-four observers (Mean age=25.9, SD=4.5, 17 women) participated in this experiment and gave informed written consent for their participation. According to self-report, all but four observers were right-handed, and all had normal or corrected to normal vision and hearing. All observers received payment of £7.

3.1.2 Stimuli, Apparatus and Procedure

The procedure for Experiment 2 consisted of two phases, conforming approximately to the Test Phases of Experiments 1A (free choice trials) and 1B (urge trials), but with the following exceptions. Observers viewed the stimuli via a mirror stereoscope housed in an unreflective, dark box, to enable dichoptic presentation. Prior to beginning the experiment a test of eye dominance was provided in which observers were asked to extend their arms straight out and form a small triangle with your hands, framing something nearby. (e.g. a doorknob) and place it in the centre of the triangle. After closing their eyes one at a time without moving the triangle, the dominant eye was the one that placed the object in the centre. We used this information to present one of two video clips to each observer's non-dominant eye on each trial. One of the video clips showed a person (author MTM) pressing the left response button on the computer keyboard used by the observer, and the other clip showed the same person pressing the right response button. Conscious perception of this video was suppressed by simultaneous presentation of a sequence of high-contrast images (3 every 85 msec) to the dominant eye, such that conscious perception was reliably of that stimulus and not the video (when the authors viewed it and according to the naïve observers' subjective reports).

A fixation cross was presented for 5000 ms at the beginning of each trial. Then a repeating sequence of a video clip and accompanying masks (Figure 5) was presented, followed by an asterisk for 5 seconds (which blinked off momentarily every 500 msec). Observers were instructed to ignore the stimuli and to press a key with their left or their right hand in every trial without taking into account any previous choices. In the 'free choice' trials the instruction was to choose freely and independently to press the right ('m') or the left ('z') keyboard, as in Experiment 1A; during the 'urge' trials observers were instructed to monitor their own perception for any urge to press with the left or right hand and to press the corresponding key immediately (as in Experiment 1B). The order of the presentation of these two conditions was counterbalanced across observers. After every free-choice trial, the observer was prompted to rate (on a scale from 1-7) how 'free' they felt making their choice. After every urge trial, they rated how strong they felt the urge to be that prompted their response. Finally, observers answered a question about the subjective difference in performance felt between the two blocks.

3.2 RESULTS

As for Experiment 1, we plotted (Figure 6) the percentage of Congruent responses (observer responded on same side as in video clip) and Incongruent responses (observer responded on opposite side to the video clip) separately for trials with Free Choice Instructions (left-hand axis, left pair of columns) versus with 'Urge' Instructions (left-hand axis, right pair of columns). Visual inspection of the plot suggested that there was now no effect of the prime on response selection in the Free or Urge trials (confirmed in related t-tests, $t=-1.07$, $p=0.294$ and -1.38, $p=0.180$, respectively) and no significant difference between these biases in Free versus Urge trials, $t(24)=-1.35$, $p=0.189$. However, the plotted RTs in Figure 6, suggested that Congruent RTs were slower than Congruent RTs in the

Free Choice trials, but not the Urge trials. The RT data were again analysed in a two-way (this time within-observers) ANOVA with the factors Task (free-choice vs. urge) and Congruency (congruent vs. incongruent). This yielded a main effect of Task, F(1,23)=6.25, p=0.020, $\eta^2 p$=0.21, - RTs were again faster for the free-choice block than for the urge block (2514.17 and 4658.33 msec, respectively), but there was no main effect of congruency F(1,23)=1.28, p=0.269. Crucially, however, there was a significant interaction between Task and Congruency, F(1,23)=4.90, p=0.037, $\eta^2 p$=0.18, - the difference between Congruent and Incongruent RTs was larger for Free Choice trials than for Urge trials. Related t-tests confirmed that incongruent choice RTs were shorter than congruent choice RTs (t(24)=-2.49, p=0.020, *d*=0.46) in the free choice trials, (M=2324.66 and 2703.68 msec, respectively) with any non-significant trend arising in the opposite direction for Urge trials (t(24)=-1.36, p=0.187; M=4762.29 and 4554.36 msec, respectively). To investigate whether this pattern of RTs had reflected overall slower responses in the Urge trials, we reanalysed the RTs removing the three slowest RTs observers for the Urge condition and the three fastest for the Free choice condition, making RT means not differed (t(21)=0.18, ns; see Figure 7). This further ANOVA still showed an interaction between Task and Congruency (F(1,20)=5.73, p=0.026, $\eta^2 p$ =0.22) even with reduced power, suggesting that as in Experiment 1, overall longer RTs in the Urge trials had minimised, rather than exaggerated the patterns of congruency effects we noted.

At the end of the experiment, observers were asked informally about the visibility of the video clip during the task. None of them reported to have seen a hand pressing a button though some reported seeing some hands in a keyboard in a few trials, with no awareness that a key was being pressed. Brief analysis of the questions on each trial assessing how free the observer felt, or how strong their urge, are discussed in a supplementary analysis section following our description of Experiment 3.

3.3 DISCUSSION

As in Experiment 1, we found dissociation between decisions made freely and decision based on urges over the reaction times. An NCE (shorter RTs for incongruent than congruent responses) was found for free-choices, the opposite overall trend in the Urge trials. Note that one could, in principle, argue that this result was a positive compatibility effect by redefining which trials were congruent in Experiment 2 and which, incongruent. As the hand in the video clip was of a person facing toward the observer, one might argue that when the person in the video clip pressed the button on the observer's left with their right hand, that the congruent response would arise if the observer pressed the right button. While this is not crucial to our assumption that priming effects dissociate free choices from urge-based responses, we believe this is inconsistent with most previous literature (e.g., Shmuelof & Zohary, 2008). Instead, the finding of Experiment 2 seems to parallel that of Experiment 1, though in RTs, not response biases. Although this pattern of results seemed to parallel those of Experiment 1, and neither had found an effect of prime stimuli upon urge-based decisions, we intuited that this might be because the (largely unconscious) stimulus was too weak, or that it needed to be presented consciously in order to affect urges. Accordingly, we repeated Experiment 2, but using normal binocular viewing of the same video clips, without any different, competing stimulus. We had concerns that task-demands might play a larger role now that the stimuli could be reliably, consciously perceived, but hoped that the strength of the action-observation effect would overwhelm any such effects.

4. Experiment 3 – Effects of Conscious Action Observation

4.1 METHOD

4.1.1 Observers

24 observers (all over 18 years old, mean age 28.1, SD=7.2, 19 women) participated in this experiment and gave informed written consent for their participation. According to self-report, all observers were right-handed, and all had normal or corrected to normal vision and hearing. All observers received payment of £7.

4.1.2 Experimental Task and Procedure

The procedure was similar to Experiment 2, except that the video clips, now centrally positioned within the display, were no longer viewed via the stereoscope but consciously perceived in the absence of other masking stimuli.

4.2 RESULTS

As for Experiments 1 and 2, we plotted (Figure 8) the percentage Congruent (observer responded on same side as in video clip) and Incongruent (observer responded on opposite side to the video clip) responses separately for trials with Free Choice Instructions (Left-hand axis, left pair of columns) versus with 'Urge' Instructions (left-hand axis, right pair of columns). Visual inspection of the plot suggested that an NCE might be present in response bias for free choices (45.5% Congruent; SD=12.29), and the opposite pattern for urge trials (56.4% Congruent; SD=22.93) though the error bars are much larger than in Experiments 1 and 2. Indeed, although the difference between mean percentage of congruent choices for the two conditions was significant (related t-test ($t(24)=3.03$, $p=0.006$, $d=0.53$), it was only marginally significant from 50% (chance) for free choices (one-sample t-test, $t(24)=1.81$, $p=0.083$) and not so for the Urge task, ($t(24)=1.37$,

$p=0.183$). For RTs, a two-way, within-observers ANOVA with the factors Task (free-choice vs. urge) and Congruency in RTs (congruent vs. incongruent) yielded no significant terms (all $ps>0.15$).

4.2.1 Exploratory analysis of subjective 'freedom' and 'urge strength' in Expts 2 and 3

Though these ratings' primary function was to interleave a second task between choices to minimise inter-choice dependencies, we performed a crude analysis of these scores to reveal any strong correlations of subjective freedom/urge strength and object measures. We calculated, for each observer, their mean indicated subjective freedom rating and mean reported strength of urge and then compared observers with lower scores versus higher scores in terms of their response times and congruency effects. Given that our overall effects were confined (in terms of congruency) to the free-choice trials, we expected that any differences would emerge for those trials. This was not the case; high and low rating observers on the freedom ratings did not differ from one another in terms of average RT or percentage congruence for either study (RTs, both $ps>0.520$, Congruence, $ps>0.087$, this marginal pattern evident only in Experiment 2, so not further examined). Much more evident, in both Experiments 2 and 3, was that observers reporting stronger urges had faster RTs as a group in that condition (E2: 4609 vs 5906 msec, $t(20)=1.97$, $p=0.064$; E3: 1874 vs 2843 msec, $t(21)=2.68$, $p=0.01$). In plotting the relationship between reported urge strength and Congruence, we also noted a striking, chevron pattern which, when congruence was expressed in terms of absolute deviation from 50%, seemed to correlate markedly and negatively with urge strength (subsequently confirmed with a Spearman's Rank correlation test $r=-0.76$, $p<0.001$; see Figure 9). The same strong trend did not emerge for Expt. 2 ($r=-0.16$, $p=0.467$), possibly a reflection of the conscious stimuli employed in Experiment 3 but not Experiment 2. This apparent relationship, as it was only observed once, may simply have arisen by chance. Alternatively, it is consistent with the notion that strong endogenous urge signals in some observers are little affected by current external stimuli, while observers with weaker endogenous urge signals may be more subject to particularly strong, conscious external influences. We also performed the same analysis for the relationship between reported subjective 'freedom' and congruence (again as absolute deviation from 50%), which seemed to correlate negatively for Expt. 2 ($r=-0.48$, $p=0.016$) and showed a similar, but nonsignificant, trend for Expt. 3 ($r=-0.32$, $p=0.120$). These effects are again too weak to support any strong claims. We hope to assess them further in future work.

4.3 DISCUSSION

Experiment 3 supported one finding from Experiment 1 and 2, of differential congruence effects in free choices versus urge based responses. Beyond this interaction, the pattern of responses was rather variable across observers, some seemingly adopting a conscious strategy of following the video, others doing the opposite. We anticipated that such conscious strategies would tend to generate very variable absolute congruency effects across different observers, masking the effect of prime congruency on free choices somewhat. However, despite this additional variation, the *difference* between congruence effects in free choice trials versus urge trials was as strong, or stronger than in Experiments 1 and 2. This pattern suggests that each individual's strategies, common to free- and urge-trials are overlaid on independent effects of the (in Experiment 3) *conscious* action-observation stimuli.

5 GENERAL DISCUSSION

Over the last thirty years, neuroscience has addressed the philosophical question of free will, focussing in particular on whether free choices can be predicted from their unconscious physiological antecedents. However, philosophers have resisted such conclusions, suggesting that when neuroimaging studies ask observers to respond when they ‘feel an urge’, this is conceptually distinct from asking them to make a free choice. Accordingly, neuroscience may have misdirected its measurements at cognitive processes that are distinct from those that philosophers consider to be free choices. When philosophers discuss whether choices are ‘free’ in the sense of being predetermined or not, they seem not to refer to urges (that might reflect mechanisms of e.g., homeostasis) but rather, choices (or picking).

This distinctiveness of a free, ‘spontaneous’ choice versus a spontaneous urge to choose one particular option does not loom as large in the neuroscience literature, in which the term ‘free choices’ normally refers to choices that are not imposed on the observer by an external factor (Passingham & Lau, 2006) or not specified by external cues (free in a Hobbesian sense). This inclusive definition also encompasses acting on the basis of feeling an endogenous urge. Indeed, without a clear *empirical* distinction between free choices and spontaneous urges there has been no way to resolve this debate. On the one hand, there seems only a very slight pragmatic distinction between asking someone to choose freely one of two arbitrary options versus to choose one of those options on the basis of feeling a spontaneous urge to do so. On the other hand, an endogenous itch, for example, may be considered as closely related, perhaps equivalent to, an urge to scratch, but seems entirely distinct from a freely-made choice to scratch. Similarly, in smokers, the urge to smoke (when no relevant stimulus is present) is not equivalent to free choosing to smoke.

The aim of the present series of studies was to reveal a clear *empirical* dissociation between free choices and decisions based on spontaneous urges. To our knowledge, ours is the first study to attempt this, manipulating the task instructions given to observers. One obvious distinction between free choice and urge based responses is that response times (RTs) are in general faster for the former. A possible explanation according to observers´ reports is that they normally took longer in waiting for feeling an urge than when deciding to act freely. However, such data alone cannot provide an adequate distinction between the two conditions to suggest that they are different processes. Faster RTs in one condition than the other would still be consistent with a single noisy generator process underlying the two responses, but observers adopting different thresholds for responding under the two sets of task instructions. Indeed, when we took standardized scores of the two sets of RTs, the distributions were similar with no obvious differences in kurtosis or skewness across experiments.

Rather the distinction observed here between free choices and urge based responses pertains to the effects of prime stimuli. We did not predict the pattern of findings that arose in our three experiments reported here – in each case there was a tendency for a negative compatibility effect (NCE) influencing responses when observers were asked to make free choices but not evident for responses made on the basis of endogenous urges. We did not describe here, a study similar to Experiment 3 that used the challenging letter-memory task from Experiment 1, likely minimising available capacity to process the complex prime videos. We collected a complete sample and did not find priming effects for either free or urge stimuli, presumably due to decreased ability to process the prime. This prompted use to switch to the easier task used in Experiments 2 and 3, though we hope to investigate attention-based effects in a future project. For now, the robust, recurring pattern in

Experiments 1-3 strongly suggests that urge and free choice tasks are different processes, evident in the selective presence of NCEs for free choices only.

Why might NCEs only affect free choices and not urges? One obvious source of these different effects might be the urge instructions require interoception- observers to attend to their internal states, whereas asking observers to make free choices does not explicitly direct their attention internally. Perhaps this *internal* attention rendered those urge-based responses driven by internal urges less susceptible to *external* stimuli. Alternatively, it may simply be that our observers' free choices were rather well balanced on each trial, with no strong internal or external signal driving them to choose to press either button in particular. In contrast, when an observer feels an internal urge to make one response or another, that is a much stronger directional signal (which they are instructed to respond on the basis of). Accordingly, it may be that priming effects only affect behaviour reliably in the absence of other strong influences. This latter interpretation is consistent with one of the additional analyses we performed on the data from Experiments 2 and 3. When we correlated subjective strength of felt urges across observers with proportion of congruent responses in those trials, there was a strong, linear relationship indicating that stronger perceived urges were associated with minimal influences of prime stimuli. This relationship is by no means conclusive given that it was only observed once and in only 24 observers, but it suffices to provide suggestive evidence for future research to follow-up.

Though it was not our aim, our data may also speak to debates concerning the origin and nature of the NCE. There is vast literature in how unconsciously-perceived stimuli can influence not only motor responses (Schlaghecken & Eimer, 2004; Hughes, Velmans, & De Fockert, 2009) but also cognitive control processes (Lau & Passingham, 2007; Boy, Husain, & Sumner, 2010; Rahnev, Huang, & Lau, 2012). Our new findings provide evidence that this is the case not only for classical priming paradigms but also when *no targets* are presented; it has been stated that free choice priming only occurs when the primes that are used are also being responded to as targets (O'Connor & Neill, 2011; Schlaghecken & Eimer, 2004). However, we obtained a reliable NCE in free choices, both in response congruency (Exp 1) and RT congruency (Exp 2) when no targets are presented and thus no top-down templates searches can be implemented. Accordingly it would appear that such claims to not extend to the paradigms and samples reported here.

Our results in the free choice conditions were consistent with the inhibitory threshold theory (Schlaghecken & Eimer, 2002) of NCE's. On that view, the prime's sensory strength must be sufficiently large that it triggers endogenous inhibition to prevent the system from becoming overloaded with repetitive information that is of no use. The negative congruency effect depends on the perceptual strength; strong response activations are actively inhibited, whereas weaker activations remain below a hypothetical inhibition threshold (Schlaghecken & Eimer, 2002). Our repeated prime presentation would have provided the right conditions for an NCE to emerge, on that view. Experiment 3 suggests, however, that stimuli do not need to be subthreshold in order to show similar patterns of effects to the other two experiments. Rather, that effect in the final study seems to have been overlaid with noise generated by observers' idiosyncratic strategies and assumptions relating to the experimenters' intentions (task demands) when they could perceive the primes consciously, and might guess the experimenter's intention. Though it is very difficult to ascertain whether the stimuli presented in Experiments 1 and 2 were perceived in an exclusively unconscious manner, it seems as though that presentation likely achieved our aim of minimising the effects of task demands that arise for fully conscious stimuli. This did not necessarily reduce our effects of interest, however: NCEs in the free choice conditions of Experiments 1 and 2 were as reliable, or more so, than when the stimuli were consciously presented in Experiment 3.

In conclusion, we found consistent evidence for NCEs when observers were instructed to make free-choices, but no such evidence when observers were instructed to respond on the basis of a felt urge. NCEs therefore dissociate responses made (i) on the basis of instructions to make free choices from (ii) responses made when observers are instructed to press a button when they feel an urge to do so. Over the last thirty years, neuroscientific study of questions related to the philosophical question of ‘free will’ has treated these two tasks as equivalent. They are not, and this dissociation demands that the neuroscience refine its procedures in order to study ‘free’ choices.

We hope these results will help refine tasks used at this part of the interface between neuroscience and philosophy. Only if such refinements keep pace with technical advances will neuroscience be able adequately to address such challenging topics.

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Figure Legends

Figure 1. Sequence of events in a typical trial of the Training Phase in Experiment 1. On half of trials, the prime shape was a square, always followed by the same instruction (e.g., 'left') and on the other half, the prime shape was a diamond always followed by the other instruction (e.g., 'right').

Figure 2. Sequence of events in typical trial of the Test Phase in Experiment 1. On half of the trial primes were squares and on the other half, diamonds.

Figure 3. Results from Experiment 1. Mean response rate (bars) and mean reaction times (lines) in Experiment 1A (free choices) and Experiment 1B (urges), plotted separately for incongruent and congruent responses in the Test Task.

Figure 4. As Figure 3, but for RT-equalized subsamples of Experiment 1A and Experiment 1b

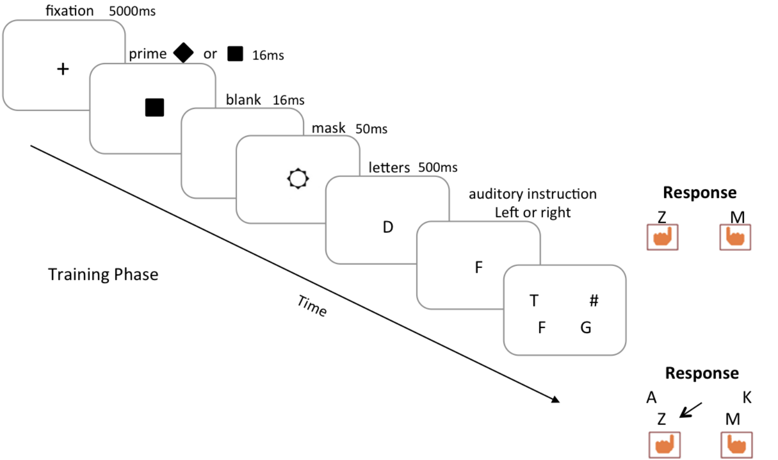
Figure 5. Stimulus events and trial structure in Experiment 2. Sequence of events in each trial. On half of the trials, the video clips showed a finger of the left of the display pressing the left response key on the keyboard used in the experiment, on the remaining trials, a hand pressing the right response key.

Figure 6. Results of Experiment 2. Mean response rate (bars) and mean reaction times (lines) in Experiment 1A (free choices) and Experiment 1B (urges), plotted for incongruent and congruent responses.

Figure 7. As Figure 6, but for subset of observers with equal overall RTs for Free Choice and Urge Conditions.

Figure 8. Results of Experiment 3. Mean response rate (bars) and mean reaction times (lines) in Experiment 1A (free choices) and Experiment 1B (urges), plotted for incongruent and congruent responses

Figure 9. Scatter diagram for the correlation between observers' urge strength ratings and absolute deviations from chance of percentage congruent responses. The x-axis is the scale on the questionnaire scores. The Y-coordinate of each point is the percentage on the response bias for (in absolute values).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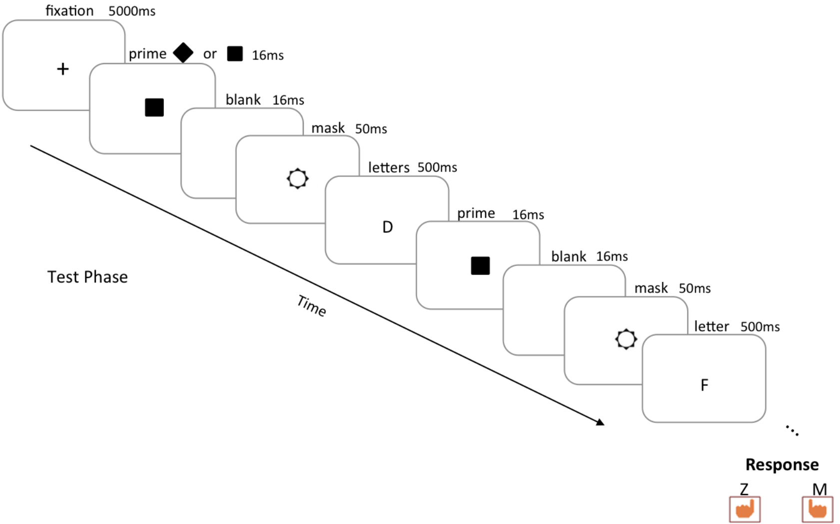
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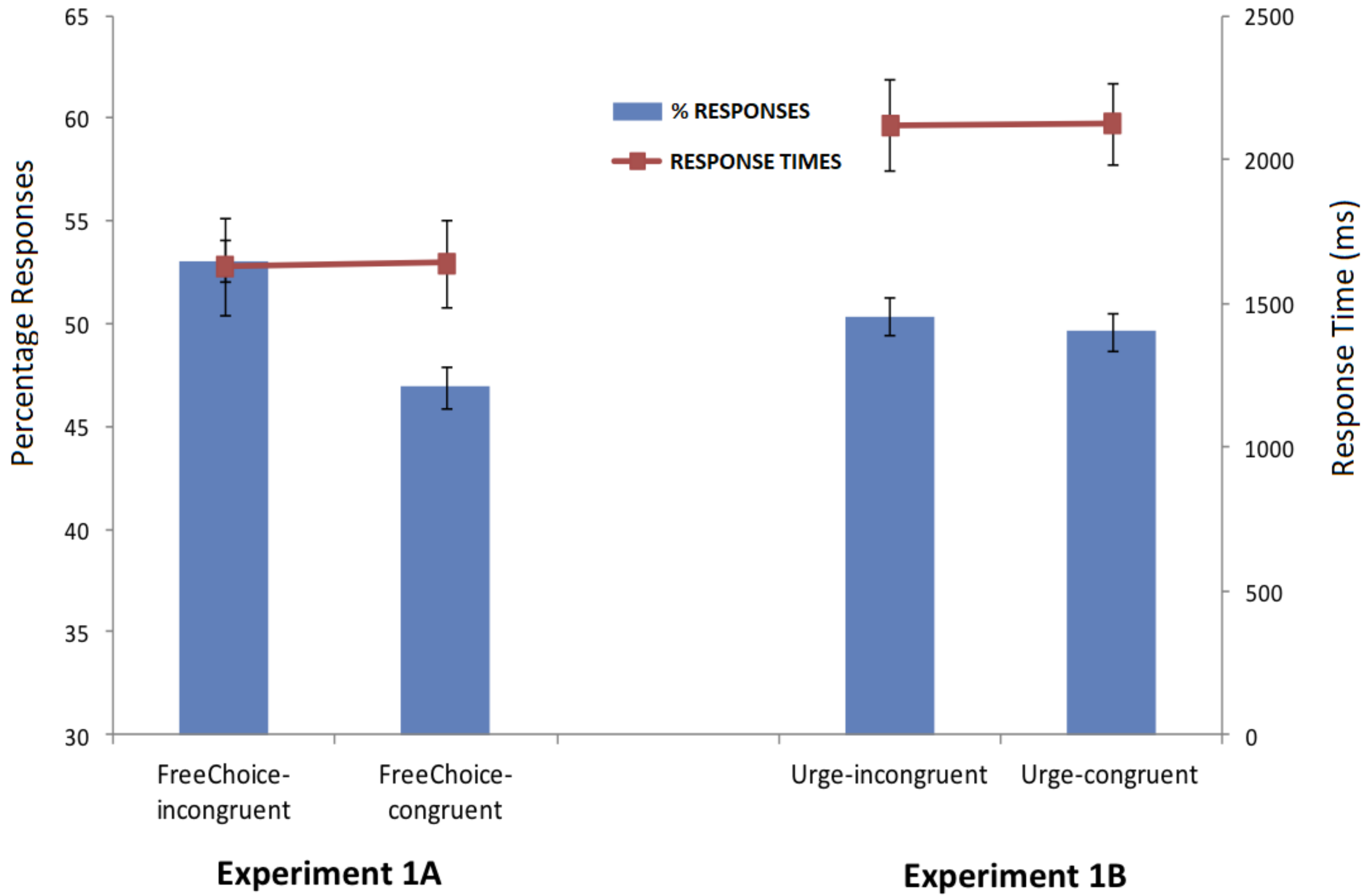
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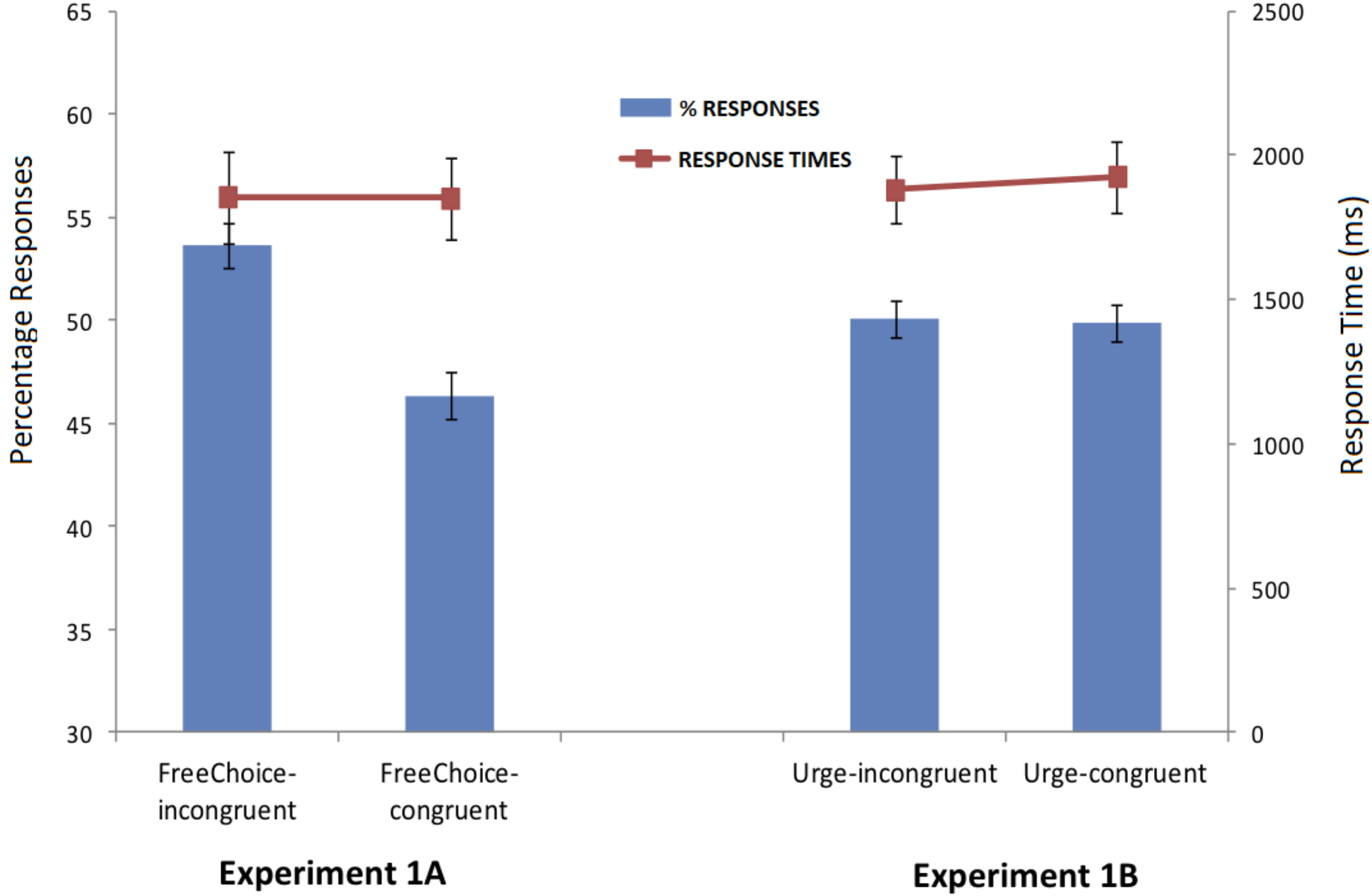
Experiment 1B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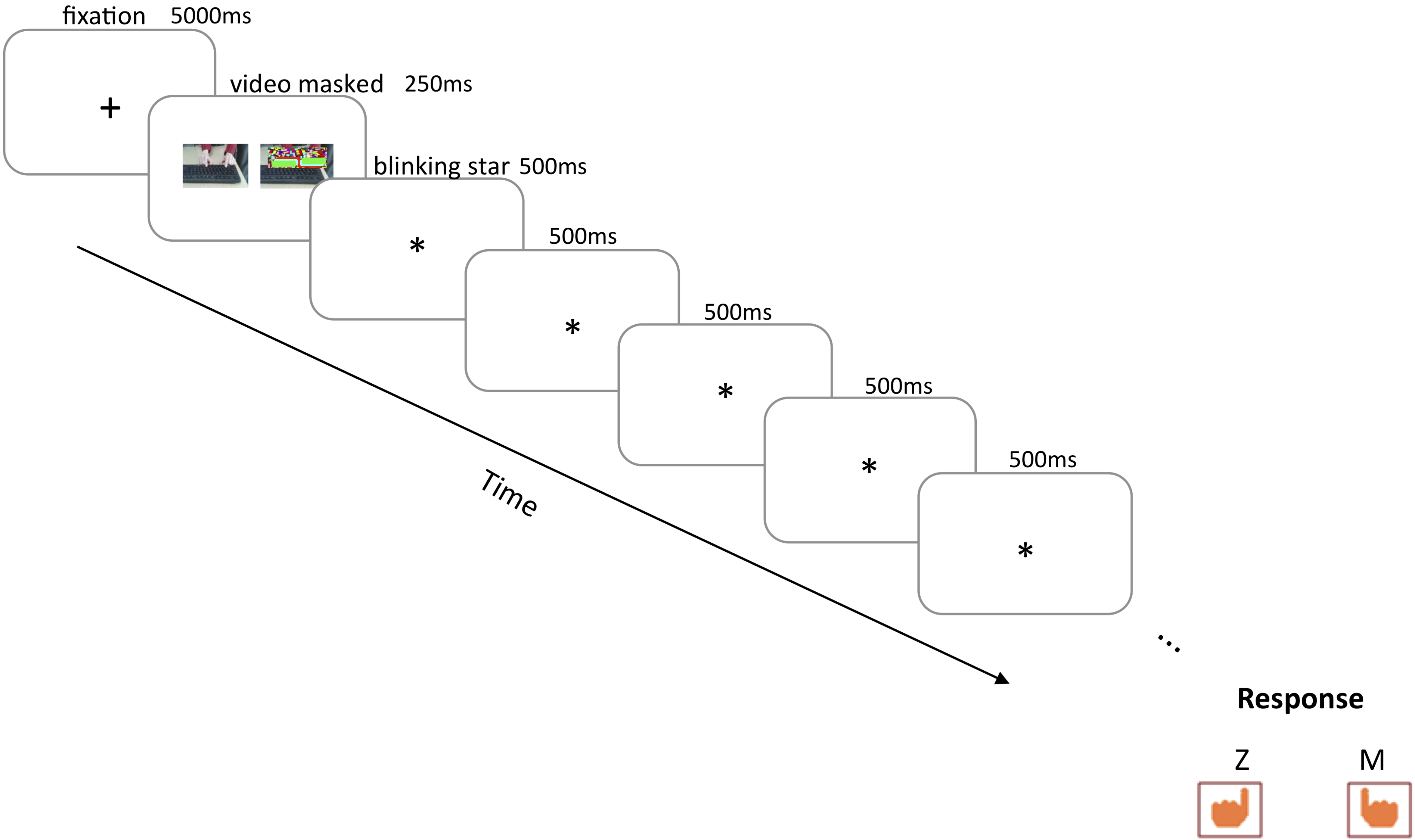
Experiment 1A
Experiment 1B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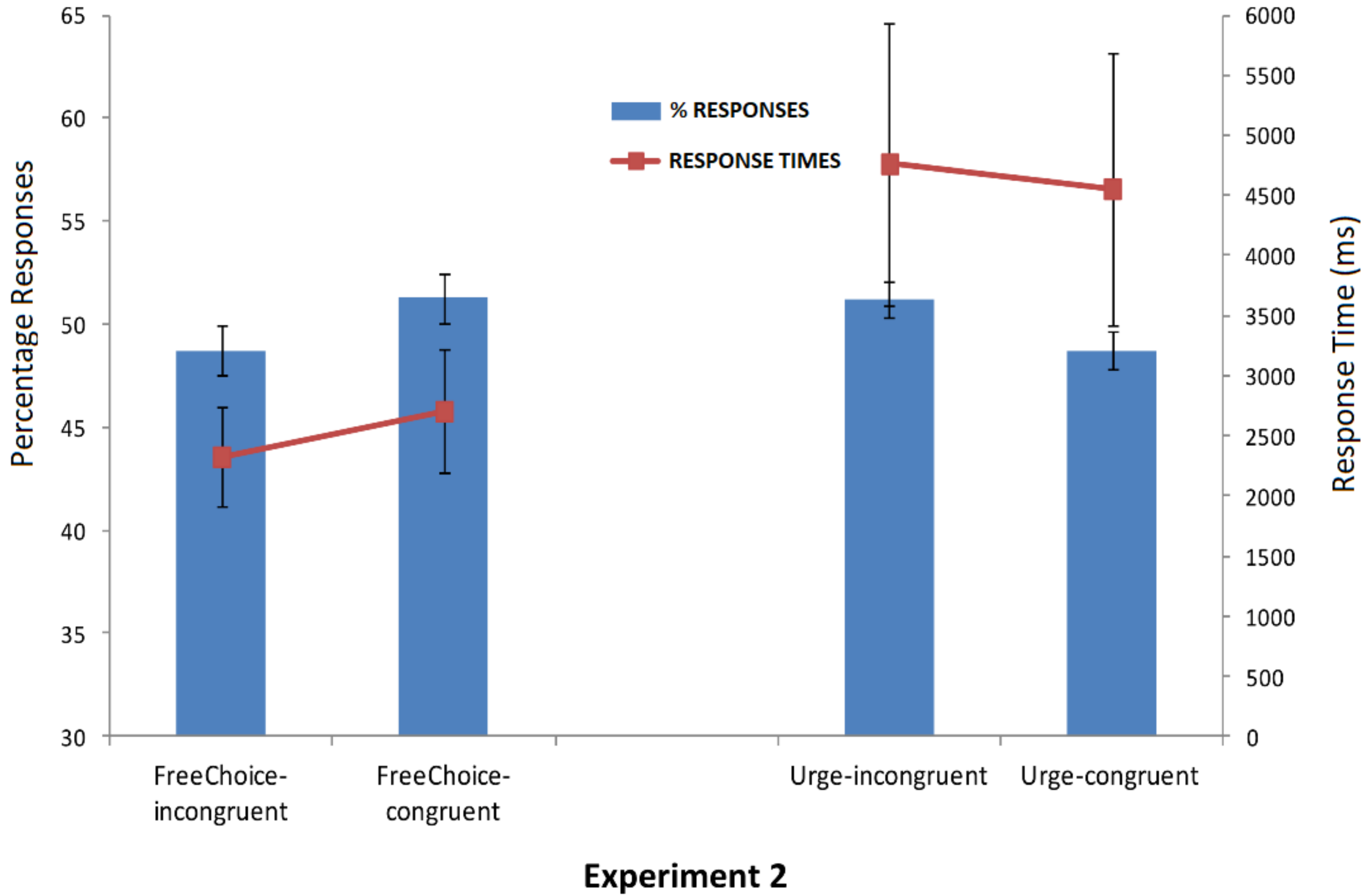
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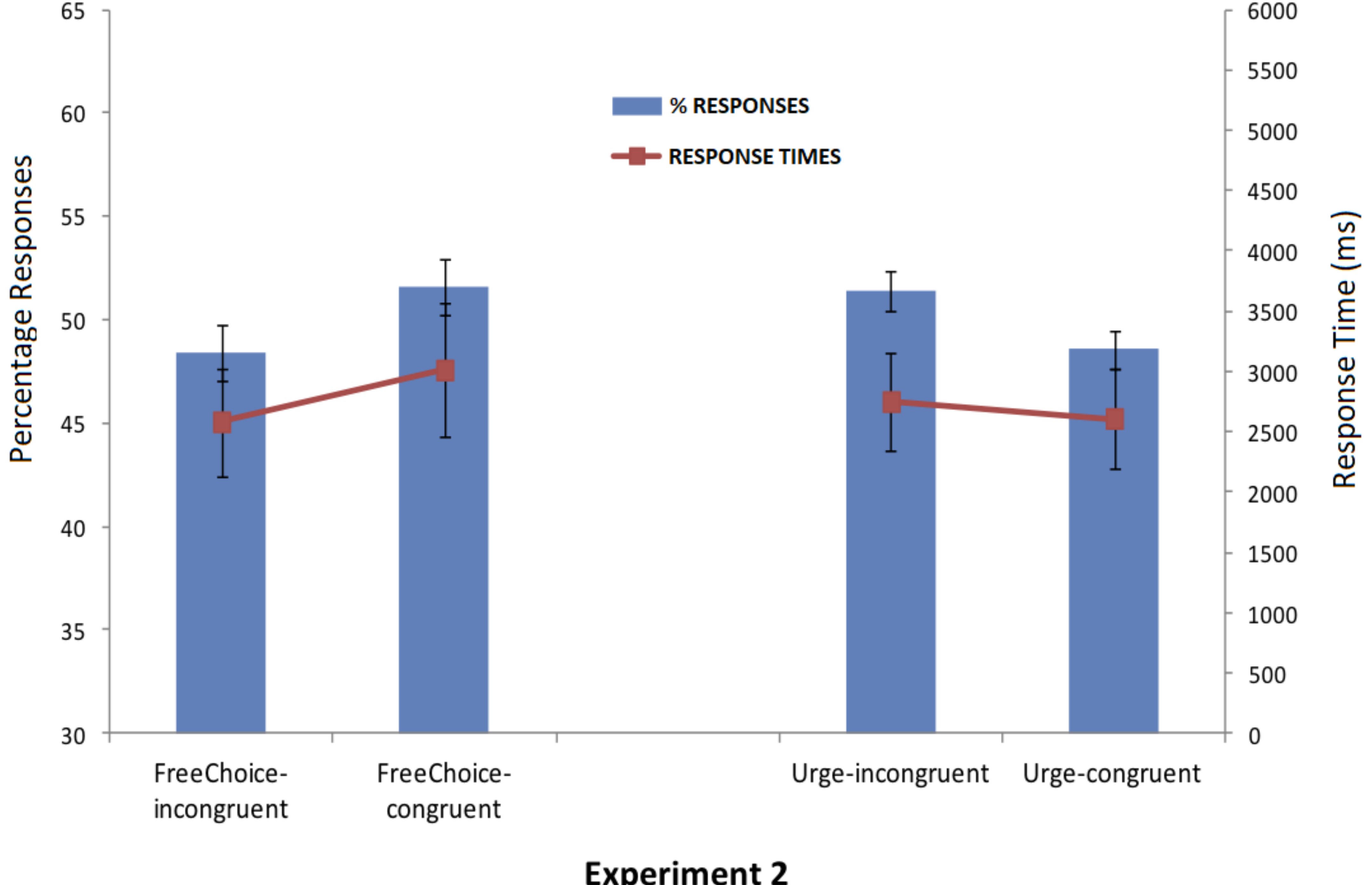
Experiment 2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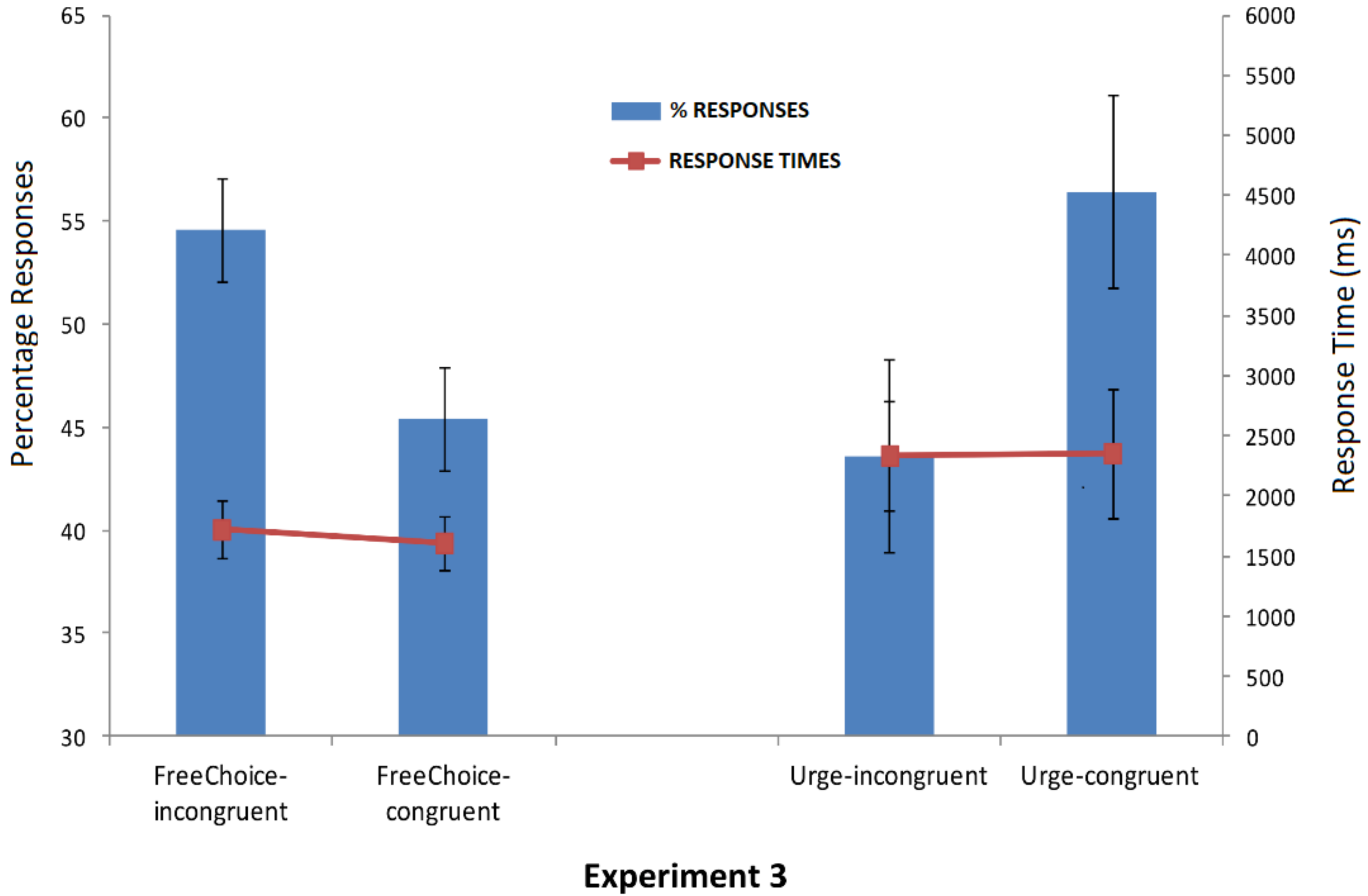
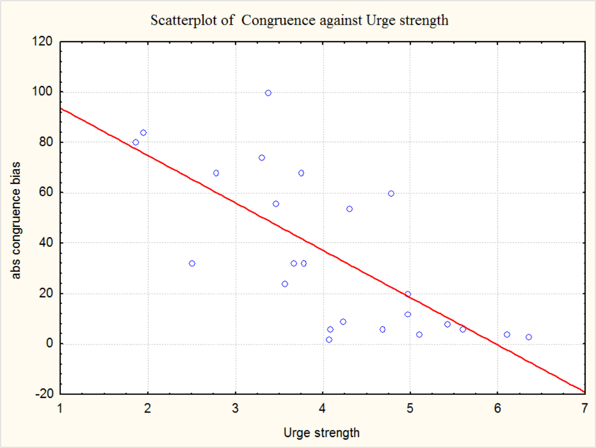
Response Time (ms)
% RESPONSES
RESPONSE TIMES
FreeChoice-incongruent
FreeChoice-congruent
Urge-incongruent
Urge-congruent
Experiment 2


% RESPONSES
RESPONSE TIMES
Percentage Responses
Response Time (ms)
65
60
55
50
45
40
35
30
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
FreeChoice-incongruent
FreeChoice-congruent
Urge-incongruent
Urge-congruent
Experiment 3



Scatterplot of Congruence against Urge strength
abs congruence bias
Urge strength
120
100
80
60
40
20
0
-20
1
2
3
4
5
6
7