UNIVERSITY OF PADOVA

Department of General Psychology

Bachelor's Degree Course in Psychological Science

Final Dissertation

Which Stimuli Can Trigger Control Adaptation?

Supervisor

Professor Roberta Sellaro

Candidate: Selin Kaya

Student ID number:1229838

Academic Year: 2022/2023

Abstract: The conflict monitoring theory posits that conflict trials generate an aversive or negative affective signal, prompting heightened cognitive control in subsequent trials. This adaptive response enhances performance following conflict trials compared to non-conflict trials, exemplifying control adaptation. Furthermore, prior research has demonstrated that aversive stimuli, even in the absence of conflict, can trigger control adaptation. Notably, instances of low perceptual fluency engender negative affective responses that stimulate increased cognitive effort. This investigation aims to advance comprehension of the triggers for control adaptation in the absence of conflict, focusing on the evaluation of asymmetric stimuli vis-à-vis symmetric stimuli. The overarching objective is to determine whether, and to what degree, reactive behavioral adaptation can be evoked by asymmetric stimuli, thus enriching insights into the mechanisms underlying cognitive control adjustments.

The interplay between cognitive control and conflicts constitutes a foundational aspect of the neurocognitive mechanisms underlying the regulation of human behavior in challenging circumstances. Cognitive control denotes the cerebral aptitude to orchestrate and steer cognitive processes—comprising attention, memory, decision-making, and problem-solving—towards the attainment of specific objectives or tasks. This is further characterized as the cognitive faculty enabling the deliberate regulation of cognitive activities and actions with the intent of achieving designated goals, all the while countering distractions and curtailing automatic responses.

Conversely, conflicts manifest when disparate or incongruous responses or information necessitate resolution (van Steenbergen & Band,2013). These conflicts are emblematic of discordant signals, emblematically indicating the exigency for cognitive control and inciting mechanisms of affective counter-regulation.

The signal of aversive conflict serves as a catalyst for successive conflict adjustments, potentially entailing direct conflict resolution or the deployment of affective counter-regulatory strategies to mitigate the disagreeable affect associated with conflicts (Inzlicht, Bartholow, & Hirsh, 2015).

A conflict task is a cognitive paradigm intentionally designed to induce a condition of conflict in an individual's decision-making or response selection processes. This involves presenting stimuli or conditions that provoke conflicting or incongruous response tendencies, leading to a dilemma in choosing the most appropriate response option.

Examples of illustrative conflict tasks include the Stroop task, where participants are instructed to verbalize the color of ink while inhibiting the automatic inclination to read incongruent color words (e.g., saying "blue" when the word "RED" is printed in blue ink) (Jensen & Rohwer, 1966).

The Flanker task is a cognitive paradigm that involves a central target stimulus surrounded by distractor stimuli. Participants are required to respond to the central target while suppressing responses influenced by the surrounding distractions (Sanders & Lamers, 2002). On the other hand, the Simon task is designed to elicit cognitive conflict. In this task, participants are instructed to respond based on a designated attribute, such as the left/right location of a stimulus. However, the actual location of the stimulus may contradict the required response, leading to a conflict between the instructed response and the stimulus location (Isherwood, Keuken, Bazin, & Forstmann, 2021).

The Go/No-Go task directs participants to execute a response (Go) to one stimulus type while withholding their response (No-Go) to another, inducing conflict between response propensities. (Georgiou & Essau, 2011). Across these exemplifications, conflict emerges from the intersection of competing response alternatives, with participants' performance therein reflecting their competence in efficaciously managing and resolving the intrinsically conflicting information.

Embedded within these paradigms, cognitive control processes assume a role in the detection of conflicts arising from the coexistence of multiple responses or disparate information. A tangible illustration is discerned when individuals grapple with deciding between two equitably appealing options, whereby conflict materializes as the brain deliberates over the merits and demerits associated with each alternative.

Intrinsic to the cognitive architecture is a specialized monitoring apparatus tailored to detect and register conflicts. The monitoring system plays a pivotal role in identifying contexts that require cognitive control to resolve conflicts and enhance judicious decision-making. Its primary function is to promptly signal the onset of conflict, thereby initiating adaptive modifications within attentional filters and control mechanisms. These precise adjustments are systematically fine-tuned to align with the distinct requirements intrinsic to the ongoing cognitive task or process (Schmidt, 2023).

The Conflict Monitoring Theory posits that the identification of conflicts within the context of cognitive tasks elicits the emergence of an aversive signal, thereby instigating an augmentation of cognitive control and consequent enhancements in performance during subsequent trials (Dignath, Eder, Steinhauser, et al., 2020)

The cerebral apparatus orchestrates a repertoire of processes geared towards the prioritization and selection of optimal responses or courses of action. Cognitive adaptation, in this context, epitomizes a dynamic cognitive process characterized by the accommodation to emergent or evolving circumstances through the recalibration of cognitive faculties, inclusive of attention, perception, and memory.

Upon the detection of conflicts, cognitive control mechanisms are invoked to effectuate adaptation and conflict resolution. This multifaceted process entails the capacity to assimilate novel information and recalibrate preexisting knowledge, thereby facilitating an effective response to evolving situational demands (Dignath, Eder, Steinhauser, et al., 2020).

Processing fluency, on the other hand, is defined as the ease with which information flows through the cognitive system. This ease of processing is affectively positive: People prefer things they can perceive or apprehend easily (Reber, 2011)

After the proposition that heightened fluency induces a positive affective response and even this affective response, in turn, can be effectively quantified using psychophysiological measures, (Winkielman, Schwarz, Reber, & Fazendeiro, 2003), numerous preceding studies have consistently demonstrated that disfluency represents an aversive stimulus (Alter et al., 2007), (Dreisbach, Reindl, & Fischer, 2018). When a task is perceived as effortless or smooth, individuals tend to rely on heuristic and intuitive information processing strategies. Conversely, when confronted with tasks deemed challenging or demanding additional effort, individuals tend to favor more meticulous and analytical processing methods (Alter et al., 2007).

Perceptual fluency denotes the expediency and facility with which the human brain processes and recognizes sensory inputs, spanning visual, auditory, and tactile stimuli. When a sensory input is characterized by perceptual fluency, it is swiftly and effortlessly apprehended, comprehended, or processed by our sensory and cognitive faculties.

The modulation of perceptual fluency is influenced by an array of factors, including familiarity, simplicity, clarity, and repetition. For instance, a familiar word or image is likely to be promptly and easily recognized in comparison to an unfamiliar counterpart. Similarly, information presented with lucidity and directness attains a heightened level of perceptual fluency in contrast to information presented in a convoluted or perplexing manner. (Reber, Winkielman, & Schwarz, 1998)

Recent research has expanded our understanding of control adaptation, showing that it applies not only to conflict situations but also to responses triggered by aversive stimuli unrelated to conflicts and studies investigating the relationship between low fluency and heightened cognitive effort have revealed that challenges in information processing prompt individuals to increase their cognitive exertion.; Hyunjin Song and Norbert Schwar's study on willingness of the participants to engage in the delineated behavior revealed that participants exhibited diminished willingness to embrace the depicted behavior in comparison to scenarios where instructions were conveyed through an easily legible font by illuminating that instructions presented in a font characterized by challenging legibility elicited perceptions that the behavior would necessitate an extended temporal commitment, manifest reduced fluency and naturalness, and entail heightened skill requirements(Song & Schwarz, 2008), In Kensinger's study, it was also observed that the experience of diminished perceptual fluency elicits a negative affective response, prompting individuals to exert heightened cognitive exertion (Kensinger, 2009) ,Dreisbach and Fischer's study on comparing two theories about ACC function (conflict monitoring and outcome evaluation) through three experiments, revealed that low perceptual fluency, an aversive signal, prompted cognitive effort adjustments even without response conflicts.(Dreisbach & Fischer, 2012)

To provide further evidence that the trigger function of aversive conflict and disfluency depends on the affective context they are embedded in, Gesine Dreisbech and her colleagues revealed the motivational underpinnings behind context-specific processing adjustments engendered by aversive signals, emanating from experiences of conflict or disfluency (Dreisbach, Reindl, & Fischer, 2018). The researchers discerned that the fluency effect exhibited diminished proportions after encounters with disfluent words. In essence, when participants grappled with the intricacies of comprehending the spoken number words, typified by low perceptual fluency, a discernible surge in exerted cognitive effort and consequential processing adjustments transpired. This inference proposed that in instances wherein speech signals posed challenges in comprehension, prompting low perceptual fluency, individuals demonstrated heightened endeavor and adaptive processing adjustments to enhance task performance accuracy. (Dreisbach, Reindl, & Fischer, 2018)

Throughout the history of cognitive research, the examination of cognitive disparities between symmetric and random patterns has been a subject of consistent interest (Bornstein et al., 1981; Reber, 2002). Several researchers have postulated the potential existence of a temporal advantage in detecting symmetric patterns as opposed to asymmetric ones (Bornstein et al., 1981; Reber, 2002). Furthermore, certain studies have indicated that participants exhibit slower response times when presented with random patterns compared to reflection symmetry (Bruce & Morgan, 1975; Makin et al., 2012).

These findings align with the fluency hypothesis, which claims that individuals' preferences for symmetry are influenced by the favorable emotional response elicited by the ease of processing (Carbon, Grüter, Grüter, Weber, & Lueschow, 2010; Pecchinenda, Bertamini, Makin, & Ruta, 2014). Empirical evidence demonstrates a positive association between visual symmetry and emotional positivity when utilizing indirect measures to assess affect (Bertamini, Makin, & Pecchinenda, 2013). This association becomes particularly prominent when the classification task prioritizes the recognition of pattern regularity.

Makin, Pecchinenda, and Bertamini conducted an experiment using dot-patterns, some of which were symmetrical while others were random, along with positive and negative words (Makin, Pecchinenda, & Bertamini, 2012). The experiment involved compatible and incompatible blocks, where participants were assigned keys to classify symmetry or positive words, as well as random or negative words. The response time difference between compatible and incompatible blocks served as an indicator of the strength of the association between positive words and reflective symmetry. The results revealed that participants showed quicker responses when the same key was used to classify reflection dot-patterns and positive words, while a different key was employed for random dot-patterns and negative words. These findings, along with those from the Implicit Association Test (IAT), suggest a preference for reflection symmetry dot-patterns over random ones.

In the pursuit of understanding the intricacies of human perception, cognitive biases, and neural processing as they relate to symmetrical stimuli, researchers have undertaken investigations in this domain (Palmer, 1985; Treder, 2010; Evans et al., 2012). Outcomes of these inquiries have underscored a distinct preference for associating positive emotions, particularly happiness, with facial expressions linked to words connoting symmetry, while negative emotions, such as disgust, tend to be linked with words connoting asymmetry. (Chuquichambi, Corradi, Munar, & Rossello Mir, 2021)

In conclusion, the researches until now have demonstrated that aversive stimuli, even in the absence of conflict, can trigger control adaptation. Notably, instances of low perceptual fluency engender negative affective responses that stimulate increased cognitive effort. Asymmetry, similar to disfluency, has been noted for its capacity to elicit unfavorable affective responses (Bertamini, Makin, & Pecchinenda, 2013). Nevertheless, in contrast to disfluent stimuli, asymmetric stimuli do not inherently present heightened challenges concerning response. This discernible contrast has instigated our inquiry into whether asymmetry can incite adaptive behavioral responses in the absence of conflict or perceived complexity. Specifically, this study aims to explore the effects of asymmetric stimuli compared to symmetric stimuli on reactive behavioral adaptation. By examining whether and to what degree asymmetric stimuli can evoke cognitive control adjustments, this research seeks to provide valuable insights into the factors that drive control adaptation, thereby enhancing our comprehension of the processes involved in cognitive control and its modulation.

Method

This study is part of a larger research effort aimed at expanding our understanding of control adaptation triggers in the absence of overt conflict. The current study focuses specifically on the comparison between asymmetrical and symmetrical stimuli, aiming to contribute empirical insights that align with the broader research goal, shedding light on the nuances of control adaptation dynamics in response to varying visual stimuli configurations.

Participants:

A total of 84 participants took part in a comprehensive research project with the primary objective of evaluating stimuli capable of instigating reactive behavioral adaptation. This encompassed the execution of three distinct tasks. Participants were assigned randomly to one of these three tasks, each varying in terms of the type of stimuli utilized. Specifically, 27 of the participants were randomly allocated to engage in a color discrimination task (focused on symmetry), which is the subject of the current study.

Within the 27 (13 Female, 13 Male, 1 Non-Binary) participants, age ranged from 20 to 31 years (M= 24.24, STD= 1.420).

The participants were chosen based on stringent inclusion criteria, ensuring their suitability for the research objectives. The criteria encompassed normal or corrected-to-normal vision, the absence of color vision deficiencies, no history of intellectual disability, no diagnosed psychiatric disorders, and non-regular use of hard drugs. Prior to their participation, all individuals provided written informed consent through the Gorilla online software platform, which was utilized both for demographics questionnaire and for conducting the tasks. The study was conducted in strict adherence to the ethical principles outlined in the Declaration of Helsinki, and formal approval was obtained from the local committee of the School of Psychology (protocol number 5353).

Stimuli and Apparatus:

The experimental stimuli employed in this research encompassed a set of eight distinct dot patterns. Participants were assigned the task of discriminating the color of these dots, categorizing them as either white or black. The manipulation of dot pattern organization constituted a pivotal aspect of this study, involving a deliberate alteration of their arrangement into either symmetric or randomized configurations. This organizational distinction was consistently applied to both white and black dots.

Within the subset of white dots, four patterns were characterized by a randomized arrangement, while the remaining four exhibited a symmetrical layout. A corresponding pattern distribution was adhered to within the collection of black dots. Participants were given explicit instructions to assume a specific hand position on the keyboard, specifically placing the index finger of their left hand on the 'Z' key, and the index finger of their right hand on the 'M' key. Subsequent to this, they were directed to press the 'Z' key if the dot pattern appeared in white, and the 'M' key if the pattern appeared in black. It is noteworthy that the organizational arrangement of the dots was intentionally rendered task-irrelevant throughout the experiment.

Procedure:

Participant recruitment for this research study was conducted by requesting individuals to voluntarily participate through the dissemination of a research page link. Prior to the commencement of any trial, participants were promptly informed, upon their agreement to participate via the provided link, about the necessary environmental conditions required for conducting the research. Specifically, participants were instructed to ensure a quiet and undisturbed environment during the duration of the study. Participants were prompted to activate the full screen mode prior to commencement. Before initiating the task, all participants were requested to provide informed consent and complete a demographics questionnaire. This questionnaire encompassed inquiries regarding gender, age, highest level of education attained, and handedness.

Each trial began with a 250-millisecond presentation of a fixation cross, followed by the display of an image at the center of the screen, with a standardized size of 210x210 pixels. The image remained on screen until a response was provided. After an inter-trial interval (ITI) of 1000 ms in which the screen turned blank the next trial started. Feedback was provided in case of errors. If the accuracy percentage fell below the required level (80%), the practice block was repeated. Prior to the main trials, participants completed a practice trial to familiarize themselves with the task. The second practice block was provided only if accuracy in the previous black was below 80 %. The first practice trial included the presentation of 16 images, comprising an equal distribution of 8 white and 8 black colored images at the center of the screen. Subsequently, the second practice trial commenced with another set of 16 images, again consisting of 8 black and 8 white color-contoured images. Upon completion of the second practice trial, participants were informed to commence the block when they felt prepared.

The main trial phase consisted of three blocks, each containing 112 trials. Short breaks were provided between each block, allowing participants to rest before initiating the subsequent block of trials. During the trials, images of dots were displayed exclusively in either white or black color contour at the center of the screen.

The main trials encompassed a balanced composition of 50% symmetric and 50% random trials and within each trial, stimuli were distributed equally, with 25%symmetric organized black, 25%symettric organized white, 25% random organized white, and 25% random organized black color contoured pattern of dots. All trials for each participant were implemented within a single day, ensuring consistency and minimizing potential confounding factors.

Analysis:

The analysis conducted in this study used a repeated measures analysis of variance (ANOVA), often referred to as a within-subjects ANOVA. The factors "Symmetry in N" (symmetrical vs.

random stimuli and "Symmetry in N-1" (symmetrical vs. random stimuli are the within-subjects factors that were manipulated and analyzed to examine how participants' reaction times (RTs) and error rates are influenced by these factors.

Results

The set of descriptive statistics pertaining to demographic variables encompassed age, gender, level of education, and nationality. The age range of the sample varied from 20 to 31 years (M= 24.24, STD= 1.420). Among 27 in total, 13 of the participants were female (48.148%), 13 of the participants were male and 1 of the participants was non-Binary (3.74%).The participants exhibited three distinct levels of education attainment which were as follows: bachelor's degree (51.852%), master's degree (18.519%) and a high school diploma (29.63%).In total, 18 participants were Turkish (66.667%), 1 participant was American (3.704%), 7 participants were Italian (25.926%) and 1 participant was German (3.704%).

RTs:

For the RT data, correct RTs were submitted to a repeated measures of variance (ANOVA) with two within-subjects factors: symmetry in N (symmetrical vs. random) and symmetry in N-1 (symmetrical vs. random). The ANOVA revealed a significant interaction between Symmetry in N and Symmetry in N-1 , $F(1,26)=5.92$, $p=.02$, $\eta2= .19$ (see table 1), but no significant main effect of either factor symmetry in N, $F(1,26)= .33$, $p= .57$, $\eta2= .01$ (Mean RT symmetrical: 435 ms, random: 433 ms, see also figure 1 for mean RTs), nor Symmetry in N-1, $F(1,26)= .43$, $p= .51$, $\eta2= .016$ (Mean RT symmetrical: 433 ms, random: 435 ms). The interaction Symmetry N x Symmetry N-1 indicated that the interaction is mainly given by the fact that responses to symmetrical stimuli are faster when they follow symmetrical stimuli than when they follow random stimuli (431 ms vs 439 ms, see table 2) while responses to random stimuli are faster when they follow random stimuli than when they follow symmetrical stimuli (435 ms vs 432 ms). The response time for "Symmetrical" in both N and N-1 conditions (431 ms) is lower than when "Random" is in N and N-1 conditions (435 ms). Similarly, "Symmetrical" in N and "Random" in N-1 conditions (439 ms) have a higher response time compared to "Random" in both conditions (432 ms).

Table 1 Repeated Measures ANOVA- RTs

Within Subjects Effects

Cases	Sum of Squares	df	Mean Square	F	p	η^2_p
Symmetry in N	62.533	1	62.533	0.331	0.570	0.013
Residuals	4916.278	26	189.088			
Symmetry in N-1	87.876	1	87.876	0.434	0.516	0.016
Residuals	5270.050	26	202.694			
Symmetry in N ✻ Symmetry in N-1	823.032	1	823.032	5.918	0.022	0.185
Residuals	3616.100	26	139.081			

Note. Type III Sum of Squares

Between Subjects Effects

Cases	Sum of Squares	df	Mean Square	F	p
Residuals	291102.936	26	11196.267		

Note. Type III Sum of Squares

Table 2 Marginal Means of RT (ms)

Marginal Means - Symmetry in N

		95% CI for Mean Difference		
Symmetry in N	Marginal Mean	Lower	Upper	SE
symmetrical	435.389	414.317	456.460	10.267
random	433.867	412.796	454.939	10.267

Marginal Means - Symmetry in N-1

		95% CI for Mean Difference		
Symmetry in N-1	Marginal Mean	Lower	Upper	SE
symmetrical	433.726	412.644	454.808	10.274
random	435.530	414.448	456.612	10.274

Marginal Means - Symmetry in N ✻ Symmetry in N-1

			95% CI for Mean Difference		
Symmetry in N	Symmetry in N-1	Marginal Mean	Lower	Upper	SE
symmetrical	symmetrical	431.726	410.398	453.055	10.420
random		435.726	414.397	457.054	10.420
symmetrical	random	439.051	417.723	460.380	10.420
random		432.009	410.680	453.337	10.420

Descriptives plots

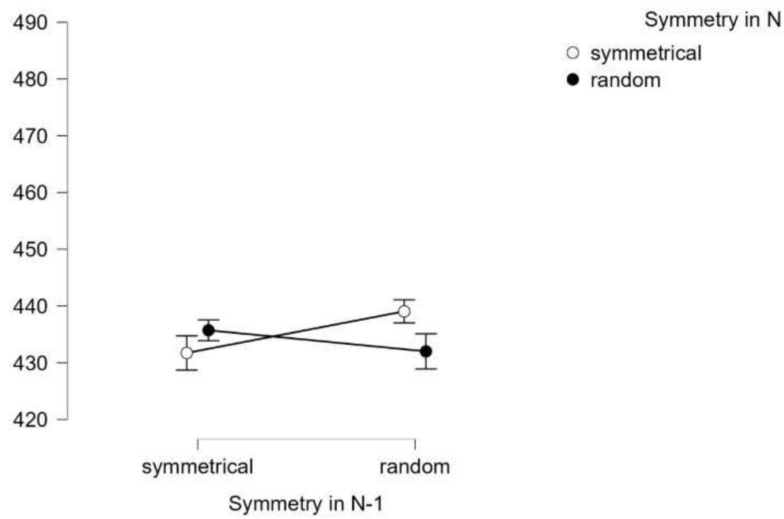

Fig. 1. Mean RTs (ms) as a function of Symmetry in N and Symmetry in N-1.

Errors:

Error rates (PE) were submitted to a repeated measures of variance (ANOVA) with two within-subjects factors: symmetry in N (symmetrical vs. random) and symmetry in N-1 (symmetrical vs. random). As shown in the ANOVA table below, none of the main effects or the interaction were significant (see table 4). For Symmetry in N ($F(1, 26) = 2.369$, $p = 0.136$, $\eta^2 = 0.084$) and Symmetry in N-1 ($F(1, 26) = 1.498$, $p = 0.232$, $\eta^2 = 0.054$), no statistically significant differences were observed. Additionally, the interaction effect (Symmetry in N x Symmetry in N-1) yielded non-significant results ($F(1, 26) = 0.051$, $p = 0.824$, $\eta^2 = 0.002$).

It is important to acknowledge that the error rates remained remarkably low, a logical outcome considering the absence of any prescribed response deadline for the participants.

Table 4 Repeated Measures of ANOVA – error rates (PE)

Within Subjects Effects

Cases	Sum of Squares	df	Mean Square	F	p	η^2_p
Symmetry in N	7.787×10^{-4}	1	7.787×10^{-4}	2.369	0.136	0.084
Residuals	0.009	26	3.287×10^{-4}			
Symmetry in N-1	2.083×10^{-4}	1	2.083×10^{-4}	1.498	0.232	0.054
Residuals	0.004	26	1.391×10^{-4}			
Symmetry in N ✻ Symmetry in N-1	2.315×10^{-5}	1	2.315×10^{-5}	0.051	0.824	0.002
Residuals	0.012	26	4.578×10^{-4}			

Note. Type III Sum of Squares

Between Subjects Effects

Cases	Sum of Squares	df	Mean Square	F	p
Residuals	0.045	26	0.002		

Note. Type III Sum of Squares

Table 5 Marginal Means of error rates

Marginal Means - Symmetry in N

		95% CI for Mean Difference		
Symmetry in N	Marginal Mean	Lower	Upper	SE
symmetrical	0.017	0.008	0.026	0.004
random	0.012	0.003	0.021	0.004

Marginal Means - Symmetry in N-1

		95% CI for Mean Difference		
Symmetry in N-1	Marginal Mean	Lower	Upper	SE
symmetrical	0.016	0.007	0.024	0.004
random	0.013	0.005	0.022	0.004

Marginal Means - Symmetry in N ✻ Symmetry in N-1

			95% CI for Mean Difference		
Symmetry in N	Symmetry in N-1	Marginal Mean	Lower	Upper	SE
symmetrical	symmetrical	0.018	0.008	0.028	0.005
random		0.014	0.004	0.024	0.005
symmetrical	random	0.016	0.006	0.026	0.005
random		0.010	4.632×10^{-5}	0.020	0.005

Descriptives plots

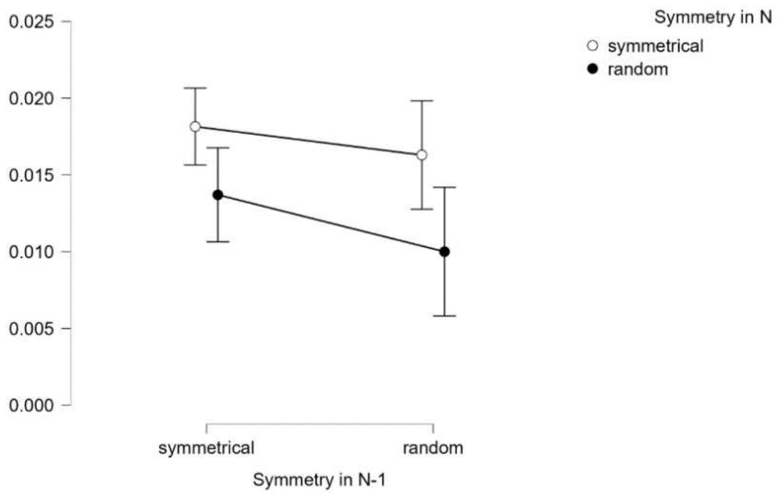

Fig. 2. Mean error rates as a function of Symmetry in N and Symmetry in N-1.

General Discussion

The objective of this study was to illuminate the understanding of whether asymmetry induces control adaptation when there is an absence of conflict, similar to the effect observed with disfluency.

As depicted in the ANOVA table provided, neither the principal effect of Symmetry in N nor that of Symmetry in N-1 attained statistical significance. In contrast, the interaction between these two factors exhibited statistical significance of note.

A visual examination of the accompanying graph elucidates that this interaction primarily arises from a specific pattern of response behavior: when participants encounter symmetrical stimuli following other symmetrical stimuli, their response times tend to be expedited. Similarly, when participants encounter random stimuli following previous random stimuli, a comparable increase in response speed is observed. Upon closer look, this recurring pattern appears to align with what can be characterized as a 'repetition effect.' Consequently, it appears that the presence or absence of symmetry, as a perceptual factor, does not appear to elicit discernible reactive adjustments in response times (RTs).

It's also important to note that while there are differences in RTs based on the combinations of symmetry conditions, these differences are relatively small (in the order of milliseconds) and may not be practically significant. Moreover, the standard errors associated with the marginal means are also relatively small, indicating a reasonably precise estimate of the means.

These findings are consistent with the relatively low error rates observed throughout the study, which is unsurprising given the absence of response deadlines for participants. The small differences in error rates among conditions, supported by the marginal means and their associated confidence intervals, may not be practically significant. Furthermore, the standard errors associated with the marginal means indicate a reasonably precise estimate of the means.

The results suggest that, within the context of this experiment, the symmetry or asymmetry of the preceding trial alone may not be a strong trigger for control adaptation.

Conclusion

It appears that, in this study, asymmetry alone may not have been aversive enough to elicit the required level of cognitive control adaptation. It is conceivable that the degree of asymmetry within the stimuli used may have been insufficient to induce observable control adaptation. Additionally, individual differences among participants, such as cognitive flexibility, prior experience, and cognitive style, could have played a role in their varying susceptibilities to control adaptation triggered by asymmetry.

Furthermore, there is a possibility that unexplored moderating variables influenced the results. It may be the case that specific combinations of task conditions, participant characteristics, or other factors were necessary to observe control adaptation in response to asymmetry.

Considering these outcomes, it is a plausible inference that in isolation, asymmetry alone may not be adequate to elicit control adaptation, as evident from both the response time (RTs) and error rate data. Therefore, to effectively employ asymmetry as a tool for inducing control adaptation, it may be necessary to introduce a conflict component to the experimental design.

In summary, the data suggests a repetition effect in response times related to the symmetry characteristics of consecutive trials. However, it does not strongly support the presence of control adaptation solely driven by symmetry or asymmetry. These findings contribute to our understanding of how perceptual features influence cognitive processes but also underscore the need for continued exploration in this area.

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