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The Influence of Sense of Agency on Implicit Learning: An Artificial Grammar Learning Task

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Abstract

Learning is most effective when individuals actively engage with new information, experimenting and integrating experiences to build meaningful understanding. Since it is recognized as an active rather than a passive process, several factors may influence how effectively individuals engage with new information. One such factor is the sense of agency, which refers to the subjective feeling of control over one's actions and may be important for learning, as it transforms experience from passive observation into active understanding. The present study aims to investigate whether differences in the sense of agency will affect implicit learning by using an artificial grammar learning task. Participants were assigned to either an active condition, where they had full control over responses, or a passive condition, where they had much limited control. Subsequently, they rated their perceived control. Results revealed that participants in the active condition reported a stronger sense of agency and achieved higher accuracy than those in the passive condition. Both groups improved over repeated trials, but the active group consistently performed better than the passive group. Overall, our study demonstrated that a sense of agency plays an important role in shaping implicit learning, thus suggesting that learning is more effective when individuals feel in control of their actions.

Key words: Sense of agency, implicit learning, artificial grammar learning

1. Introduction

Learning is primarily recognized as an active and constructive process rather than a passive absorption of information (Bada & Olusegun, 2015). According to constructivist learning theorists such as Bruner and Piaget, knowledge deepens when individuals integrate new information with existing knowledge (Bruner, 1966; Anthony, 1996; Pakpahan & Saragih, 2022). This perspective emphasizes that learning could benefit from the opportunity to explore and continuously reorganize prior knowledge (Chand, 2024).

In parallel with this view, the self-determination theory emphasizes the importance of autonomy and perceived control in developing deeper and more sustainable learning (Legault, 2017; Ryan & Deci, 2017). These perspectives together suggest that learning is a process determined not only by the information provided but also by the degree of participation and control individuals experience throughout this process. Therefore, agency may be important for learning, as it transforms experience from passive observation into active understanding. (Dunlop, 2003; Schoon, 2018). More specifically, the sense of agency (SoA) individuals experience, which refers to an individual's subjective feeling that they are in control of their actions and that those actions can influence outcomes (Haggard & Chambon, 2012; van der Wel et al., 2012; Wen & Imamizu, 2022). When learners experience a SoA, they are more likely to increase their motivation, attention, and cognitive engagement (Penton et al., 2018; Van den Bussche et al., 2020). When it is diminished, individuals engage less attentively, leading to reduced processing and poorer memory consolidation (Houser et al., 2022; Wen et al., 2016). Several studies have explored the influence of SoA on intentional learning, showing that greater perceived control enhances motivation, attention, and memory performance (Hon & Yeo, 2021; Nakashima, 2019; Ren et al., 2023). Moreover, SoA may serve as an important mechanism for the formation and organization of learning itself because it heavily relies on predictive and feedback-based mechanisms that allow individuals to connect their actions with their consequences (Haggard & Chambon, 2012). This connection is important for learning as it allows individuals to detect inconsistencies between expected and actual outcomes and adjust their behaviour accordingly (Synofzik et al., 2013).

Still, the influence of SoA on learning is not fully established in literature. For example, only a few studies have explored the relationship between sense of agency and implicit learning. This form of learning refers to the process through which individuals acquire knowledge about patterns or complex structures, without conscious awareness (Reber, 1989; Yang & Li, 2012). Unlike explicit learning, which involves intentional and conscious efforts to understand information (Masters, 1992; Sosnik et al., 2009), implicit learning operates incidentally through repeated exposure (Goujon et al., 2015). It depends on the individual's ability to detect statistical regularities and internalize rule-based patterns that guide future behaviour (Cleeremans et al., 1998). Implicit learning is considered a domain-general mechanism because it can operate across multiple cognitive domains, including the acquisition of language patterns, the development of motor skills, and the learning of social behaviours (Peñaloza et al., 2022; Rohrmeier & Rebuschat, 2012; Williams, 2020).

One of the most established paradigms for investigating the mechanisms of implicit learning is Artificial Grammar Learning (AGL) (Dienes & Berry, 1997; Dienes & Perner, 1999).In a classic AGL task, participants are exposed to sequences of letters or symbols generated from a finite-state grammar (Reber, 1967). Subsequent studies have also used other types of stimuli such as non-linguistic (shapes and colours) (Conway & Christiansen, 2006; Soares et al., 2021), auditory (tones) (Emberson et al., 2011; Heimbauer et al., 2018), or time based (durations) (Prince et al., 2018), each constructed according to specific underlying rules that are not revealed to the participant during the exposure phase (Reber, 1967). Next, the participants complete a test phase in which they are informed that all sequences follow certain rules, and they have to identify whether the new sequences conform to the rules they may have learned (Gillis et al., 2022; Westphal-Fitch et al., 2018). Performance above chance level suggests that participants have learned at least some of the underlying features or regularities (Guillemin & Tillmann, 2021). AGL has become a useful measure for investigating how people learn structured information implicitly, precisely because it enables systematic manipulation of experimental variables such as exposure, attention, and feedback (Trotter et al., 2020). It provides a highly controlled and reproducible framework in which the structure and complexity of grammatical strings can be systematically varied to test specific hypotheses about learning mechanisms. This flexibility could allow researchers to manipulate factors such as the level of difficulty or control, making AGL particularly suited for exploring how agency influences the acquisition of implicit knowledge. In traditional AGL tasks, participants typically act as passive recipients mainly observing, therefore, modifying the task to include an active component could potentially enhance learning outcomes (Gillis et al., 2022).

Despite extensive Artificial Grammar Learning research in implicit learning, the role of agency remains underexplored. Recent theories suggest that autonomy and perceived control enhance learning by aligning internal predictions with feedback from the environment, thereby reinforcing motivation and cognitive engagement (Dutta, 2025). From this perspective, SoA is not merely a subjective feeling of control but an active component that shapes how information is processed and internalized (Stern et al., 2022).

The present study aimed to investigate how the sense of agency would influence implicit learning through an artificial grammar learning task by comparing active and passive learning conditions. We hypothesized that participants who are part of the group with a full control over the choices, and consequently higher sense of agency, will be better in identifying the grammar rules compared to the participants who are part of the group with a limited sense of agency. Furthermore, we expected that participants in the active condition will report a significantly higher sense of agency, confirming that experimental manipulation successfully altered perceived control.

2. Methods

Participants

In total, there were one hundred and seventy-four participants, eighty-seven participants per condition, recruited from Prolific, the online research platform. Their age varied from 18 to 30 years (M = 24.8, SD = 3.12). The group of participants included 88 females, 86 males, and 2 individuals who declined to specify their gender. All the individuals were paid fairly in accordance with the requirements of Prolific. The criteria to be a part of this experiment were for the participants to be within the 18 to 30 years old age range and speak English fluently. To ensure that no participant was exposed to both conditions, an exclusion criterion was applied for the passive condition, where individuals who had already participated in the experiment with the active condition were not eligible to participate. The study was approved by the local Ethical Committee (Comitato Etico Regione Liguria) and was conducted in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki). Each participant provided written informed consent before taking part in the experiment by clicking on the "Yes" option at the beginning of the survey.

Design

This experiment was programmed in PsychoPy and hosted on the Pavlovia hosting service. It employed a 2 (group: active and passive) x 8 (blocks: 1-8) mixed factorial design. The condition factor was between subjects, whereas the block factor was within-subject. Performance across blocks was used to assess changes in learning over time.

Procedure

The participants were first shown written instructions describing their task and the goal of the experiment which was to identify the "grammatical" string of symbols and consequently learn the hidden set of grammatical rules. There were a total of 164 trials. First, they had a practice round of 6 trials to familiarize themselves with the task, next the main experimental session began. They were presented with two strings of symbols (located in the left and right of the screen) to choose from with no time limits and an arrow located at the bottom middle of the screen. They had to press the left or right keys on the keyboard ten times to move the arrow towards the string they thought was the correct one. They were able to choose until the last press which string they considered to be grammatical, however, they were not able to move the arrow to areas of the screen not related to the task. Once they made their choice, they would receive written feedback if it was the correct string or not, which would remain on screen for 1000ms. In the active condition, the participants had control over the arrow during all of the trials, while in the passive condition, they were instructed that in some of the trials they would be able to control the arrow and in others the computer would do so. In reality, after each 8 computer-controlled trials, participants had 2 active trials to respond autonomously.

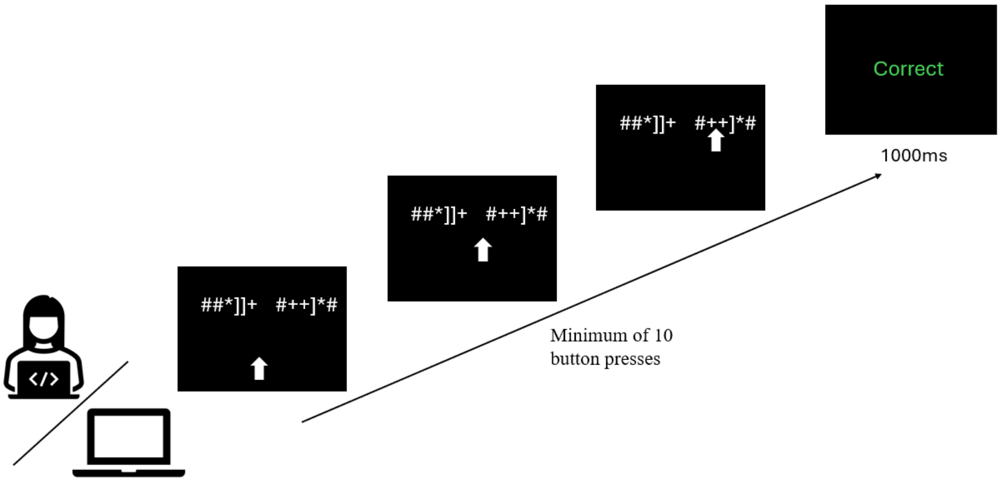

Figure 1: A representation of the trial sequence.

Upon completing the task, participants were required to rate their sense of agency over the arrow's movement. This was measured using a visual analogue scale (VAS) ranging from 1 = "I had no control at all" to 100 = "I was fully in control". They were also asked to provide a brief open-ended explanation of their rating. Finally, to assess implicit awareness of the grammar, they were asked "What do you think were the rules that the correct words followed?"

Materials and Apparatus

The stimuli used in this experiment consisted of one correct and one incorrect string of symbols combining these components: #,], * and +. Both strings had 6 symbols in total and were generated based on the two finite state grammars illustrated in Figure 2. All pairs included one string generated from Grammar A, from which the correct words were calculated, and one string generated from Grammar B, from which the incorrect words were generated. The side from which the correct word would appear was randomized. The colour of the background was set to black, and the colour of the arrow and stimuli was white. The feedback colour was green for correct and red for incorrect. The size of the symbols was 0.05 PsychoPy norm units, and the height and width of the arrow were both 0.1 PsychoPy norm units.

The creation of these strings followed the rules that Bierman et al. (2005) had in their original experiment. To generate the string of symbols, the first component was selected at random. The following elements were chosen by randomly selecting a path from the current node, following the transition probabilities set by the grammar map until all six elements had been generated. Moreover, the occurrence of strings with more than two consecutive identical symbols after the first self-transition was set to zero.

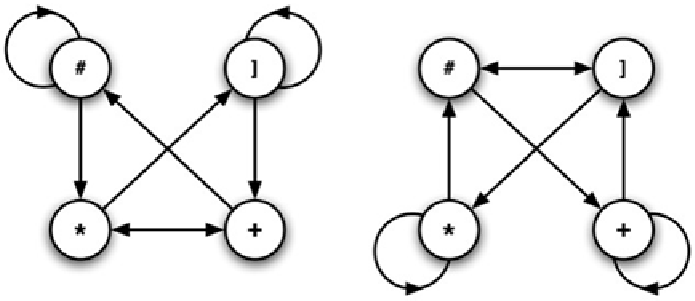

Figure 2. The two finite state Grammar A and Grammar B, from which the transition probabilities were generated from. Adapted from "Intuitive decision making in complex situations: Somatic markers in an artificial grammar learning task," by D. J. Bierman, A. Destrebecqz, and A. Cleeremans, *Cognitive, Affective, & Behavioral Neuroscience, 5*(3), 297–305 (2005).

3. Results

A 2 (Condition: active vs. passive) × 8 (Block 1- 8) mixed ANOVA was conducted on accuracy to examine changes in learning performance over time. The analysis revealed a significant main effect of Condition, $F(1, 172) = 11.10$, $p = .001$, $\eta^2 = .022$, with overall accuracy (higher for active) differing between active and passive groups. There was also a significant main effect of Block, $F(7, 1204) = 2.26$, $p = .027$, $\eta^2 = .008$, indicating that performance varied across blocks. The Block × Condition interaction was not significant, $F(7, 1204) = 0.70$, $p = .672$, suggesting that the pattern of change across blocks was similar for both groups.

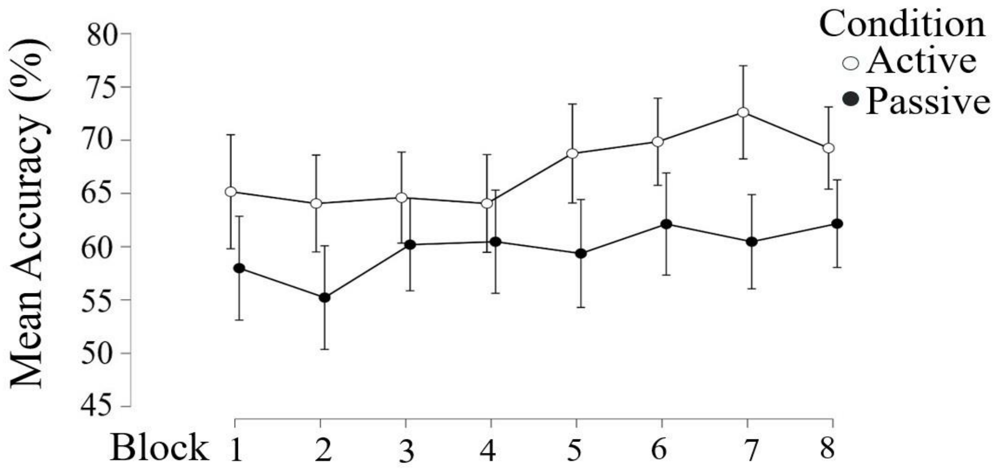

Fig.3. Mean accuracy (%) across eight learning blocks for the active and passive conditions.

To examine the subjective experience of control, an independent sample *t*-test was performed on SoA ratings. Participants in the active condition reported significantly higher SoA than those in the passive condition, $t(170) = 7.78$, $p < .001$.

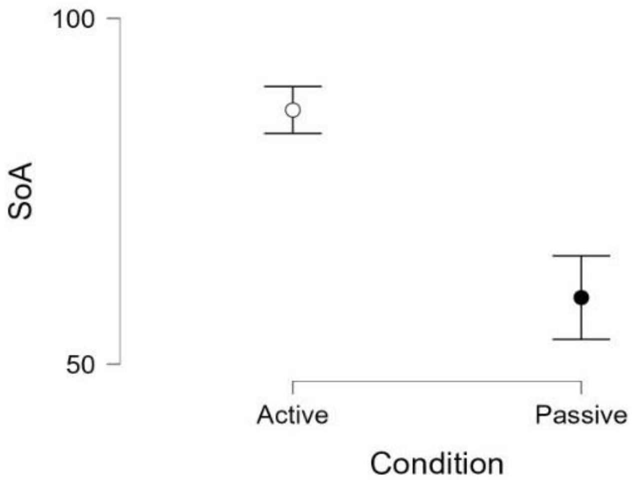

Figure 4: The difference in the reported sense of agency (SoA) between the active and passive condition groups.

Discussion

The present study explored how SoA impacts implicit learning by using an Artificial Grammar Learning (AGL) task and by comparing active and passive learning conditions. Consistent with our hypothesis, participants in the active condition, who had full control over their responses, demonstrated significantly higher accuracy in categorizing pseudowords according to a rule, compared to participants in the passive condition. Additionally, participants in the active group also reported a stronger subjective sense of agency, confirming the effectiveness of the experimental manipulation. The present findings supports the idea that having a sense of agency enhances learning performance, supporting constructivist theories of learning (Bruner, 1966; Anthony, 1996) and self-determination theory, which emphasizes the role of autonomy and perceived control in deepening cognitive engagement (Legault, 2017; Ryan & Deci, 2017). The higher accuracy observed in the active group suggests that participants who can actively make choices are more effectively able to internalize underlying structural patterns, confirming the hypothesized role of agency in facilitating implicit learning.

Notably, participants in the active condition group consistently performed better than those in the passive condition group across all eight blocks, (Fig. 3). Both groups show an improvement in the accuracy across blocks, consistent with a main effect of learning over time. However, the lack of a significant interaction between them suggests that the rate of improvement across blocks was similar between groups. This demonstrates a continuous and consistent beneficial effect of SoA on learning. The fact that already in Block 1 the pattern was consistent with the remaining blocks suggests that SoA might have affected learning already after the first eight trials of the task, thereby showing its strong and immediate modulatory effects on performance.

Interestingly, there is a slight dip in the accuracy during the final block of the active condition group. A possible interpretation for it could be due to the cognitive load and the self-determination theory (Ryan & Deci, 2017). When individuals maintain high agency throughout a long task, the demands of control and decision-making can cause a strain on attention and other cognitive functions (Hon et al., 2013; Howard et al., 2016). Another reason could also be the overconfidence reducing the attentional monitoring once they feel more comfortable with the task structure (Dunlosky & Rawson, 2012; Dutta, 2025).

While the findings provide evidence for the beneficial role of agency, several limitations should be taken into consideration. First, all participants were recruited and tested online which could have led to differences in how focused or engaged the participants were during the experiment. Also, variations in their testing environments or prior knowledge of similar tasks may have confounded the observed effects. Secondly, the age of the participants was limited to 18 to 30 years. This age range was chosen to ensure a relatively consistent level of cognitive functioning and familiarity with technology across participants, lowering the variability linked to developmental or age-related differences.

Future studies could address these limitations by examining the effect in the lab (rather than online) and across a wider range of age. This paradigm could also be explored with different populations, such as children, older adults, or people with learning difficulties, in order to learn more about how age and other individual characteristics affect the link between agency and implicit learning. Further, it would be interesting to explore the interaction between agency and other factors that influence implicit learning, for example, attentional load or task difficulty. Finally, it would be of interest to examine if SoA affects also other cognitive mechanisms, such as memory.

In summary, the results highlight the importance of considering learner involvement in experimental paradigms. This study contributes to a better understanding of how the subjective experience of control influences cognitive performance and how a higher SoA may provide a cognitive advantage in learning.

Conclusions

In conclusion, this study explored how SoA influenced implicit learning, using an artificial grammar learning task to compare active and passive conditions. By examining performance under different levels of agency, the study aimed to clarify how feelings of autonomy and control support the unconscious acquisition of structured knowledge. The results showed that participants who had full control over their actions performed more accurately than those with limited control. This finding supports the idea that when learners experience a stronger sense of agency, they might become more attentive and motivated, which enhances their ability to learn. Although both groups improved over time, the consistent advantage of the active group suggests that agency strengthens the quality of learning rather than its rate of development. Overall, this study demonstrates that agency plays a crucial role in shaping implicit learning. It highlights that learning is not merely a passive process of exposure, but an active, self-regulated experience in which control and engagement deepen understanding.

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