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The Impact of Visual Thinking Strategy Training on the Executive Functions and Visual Stimulus Preferences of University Students

Abstract

Aesthetic judgment is influenced by the perceived values of the stimuli by the beholder; nevertheless, it is also determined by the cognitive characteristics of the perceiver (such as expertise and executive functions). Although previous studies have investigated the effect of independent characteristics (such as symmetry, complexity and order) of visual stimuli on aesthetic judgment, little is known about the multi-dimensional aspects of visual stimuli. Executive functions are high-order cognitive processes; despite their frequent occurrence in the literature, there is a research gap regarding the links between training in visual arts, aesthetic judgment and executive functions. Considering the lack of evidence in the literature, the aim of the current study was to investigate the effect of visual thinking strategy (VTS) training on aesthetic judgment and on inhibition control, and selective attentional processes. Non-art university students (N = 53) were gathered and then distributed into two groups; the experimental group participated in a 7-session VTS training. We also investigated the electrical brain activity of experts (N = 2) and novices (N = 2) in visual arts. Our results indicate mixed results regarding the effect of VTS training on visual stimulus preferences between the two groups before and after training. Additionally, our results revealed significant differences between the two groups regarding reaction time in task and Flanker task. Although the results of EEG suggest functional differences between experts and novices, these results are only orientational.

Keywords: aesthetic judgement, visual thinking strategy, executive functions, EEG

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Introduction

Aesthetic judgement

Aesthetic judgement can be described as appraisals of value determined by diverse aesthetic standards, which may originate from socially constructed cognitive evaluations or emotional encounters. Aesthetic judgment is considered to be a conscious decision-making process (Egermann–Reuben 2020). Aesthetic judgement is influenced by the physical aspect of the stimuli. Hence, the physical attributes of the stimulus, including colour, arrangement, symmetry, visual intricacy and contrast, significantly influence the process, while individual traits such as age, education, familiarity and context also affect aesthetic preferences (Braun– Doerschner 2019; Kähler et al. 2020). Previous studies primarily concentrated on examining the individual effects of order and complexity on aesthetic judgement. However, when exploring both order and complexity together, the manipulations of stimuli often lacked parametric control, typically focusing on specific forms of order (such as balance or symmetry), and sometimes neglecting the multidimensional aspects of order and complexity (Van Geert et al. 2023). Thus, in order to unravel individuals' aesthetic inclinations towards order and complexity, it is crucial to independently manipulate order and complexity with precise control; explore the interplay of both factors in relation to appreciation concurrently rather than in isolation; and recognise the multifaceted nature of both order and complexity (Van Geert et al. 2021). In addition to the physical aspect of the stimuli, knowledge also has an impact on aesthetic judgement. Experts tend to form their aesthetic judgement in a more independent way, they also tend to analyse art pieces more extensively on a higher order cognitive level. Nevertheless, understanding and interpreting art is not only enhanced by knowledge of art and regular exposure to artistic encounters, but it also alters how we perceive and emotionally engage with art (Leder et al. 2015).

Visual thinking strategy

Visual Thinking Strategies (VTS) curriculum is considered a teaching method that improves critical thinking. It uses art to enhance critical thinking by highlighting attentive listening, communication and collaboration. The method also enhances reading, writing, comprehension and creative and analytical skills (Housen 2002; Landorf 2006). The method uses three questions that encourage novice viewers to contemplate evidence through questioning: "What is going on here?"; "What do you see that makes you say that?"; and "What more can you find?" (Housen 2002). This method has been successfully adapted to other disciplines outside of the art, such as in medical education (Reilly et al. 2005; Mukunda et al. 2019); the results of a systematic review also provide support for the implementation of the VTS approach in the curriculum of medical education (Cerqueira et al. 2023).

Executive functions

Executive functions refer to broad neuropsychological aspects of cognitive and behavioural capabilities. These advanced cognitive processes encompass planning, self-regulation, inhibitory control, goal-oriented behaviours like regulating conduct, and maintaining working memory and sustained attention (Dawson–Guare 2010; Barkley 2012). Executive functions, also known as cognitive control processes, are described as a comprehensive term encompassing cognitive processing guided by knowledge rather than automatic responses. Existing literature categorises the three-factor executive function model into three primary domains: inhibition, updating/working memory and shifting (Karr et al. 2018) or cognitive flexibility (Diamond 2013). Inhibitory control or cognitive control refers to behavioural regulation that aims to optimise purposeful actions while mitigating automatic responses, it is also associated with automatic and controlled responding abilities, therefore cognitive control expected to support controlled goal-directed and flexible responding (Friedman–Robbins 2022). Other scholars define executive functions as three EFs that are moderately correlated but distinctly identifiable: updating or maintaining working memory representations (updating or working memory, WM), inhibiting prepotent or irrelevant information and action tendencies (inhibition), and transitioning between various tasks or representations (cognitive flexibility or shifting) (Miyake et al. 2000).

Considering the results from the literature, the purpose of the present study is to investigate the effects of VTS methods on multidimensional visual stimuli preferences, nevertheless our aim is to examine the impact of VTS methods on inhibitory control processes.

Methods and results

Participants

42 non-artistic undergraduate students participated in the study, and convenience sampling was used. Regarding professional involvement in visual arts, 40 of the participants were not involved in visual arts (95.2%) and 2 were (4.8%) in terms of their profession. Participants were non-randomly divided into two groups, 20 participants in the control group and 22 in the experimental group (see Table 1).

Table 1: *Sociodemographic characteristics of participants*

	N	%
Gender		
Female	38	90.5
Male	4	9.5
Personal relationship with visual arts		
Not interested at all	1	2.4
Not really interested	6	14.3
Moderately interested	32	76.2
Very interested	3	7.1
Professional involvement in visual arts		
Involved	2	4.8
Not involved	40	95.2

Note: N = 42.

Source: Compiled by the authors.

The G*Power program was used to calculate the number of participants needed to test the hypotheses. With a statistical power of.80 and an effect size of.25, two groups and three measurements, 28 participants are required. The recommended sample size was met.

Materials and measures

Eriksen and Eriksen (1974) developed the Flanker Task to assess selective attention and inhibitory control. Participants in the task react to the arrow directions (< >)

that are shown on the screen. Participants must react to the middle arrow's direction among the five arrows shown on the screen during each stimulus. The middle arrow points in the same direction as the others for congruent stimuli and in the opposite way for incongruent stimuli.

We utilised the Stroop interference task (Stroop 1935) to quantify response inhibition. This task consists of 40 trials and instructions. For each trial, the name of a colour appears on the screen, and it is indicated if the colour of the colour matches the text displayed (e.g. text "blue" in blue is compatible; text "blue" in red is incompatible). Every given text colour must be responded to with the matching set of letters. The average response time in milliseconds for the compatible trials extracted from the incompatible trials is known as the "Stroop effect".

Procedure

Following enrolment in the study, individuals were allocated to either the experimental or control groups non-randomly. Participants were then provided with general information about the survey, including its topic, purpose, contact details and technical requirements for completion. Subsequently, written information was provided, and participants were given the opportunity to proceed with data collection upon giving consent. The pre-intervention pre-test was conducted in March 2023 for both groups, separated by a few days. Data collection was conducted using the online software interface PsyToolkit (Stoet 2017), version 3.3.4. Questionnaire sizes were adjusted to fit the participants' screen sizes, with a resolution of 800 × 800 megapixels utilised for all cognitive tasks. Both groups were monitored throughout the data collection process. To ensure anonymity, participants were assigned individual identification codes for completing tasks. Additionally, verbal instructions were provided, and participants were allowed to take short breaks between tasks during data recording.

The Flanker task commenced with the presentation of an instructional page detailing task requirements. Participants were informed that the screen would display a series of five arrows (e.g. <<><<), and their objective was to respond to the direction of the central arrow promptly and accurately. In instances where the central arrow pointed left (>), participants were instructed to press the "A" key, while if it pointed right (<), they were to press the "L" key. Congruent stimuli featured a central arrow facing the same direction as the surrounding arrows, whereas incongruent stimuli involved the central arrow facing the opposite direction. A total of 40 stimuli were presented during the task. Upon completion, participants were prompted to proceed by pressing the spacebar.

The Stroop interference task also commenced with instructional pages, wherein participants were presented with colour names (yellow, red, blue, or green) on the screen. The colour name displayed was either congruent or incongruent with the colour of the text (e.g. "blue" text displayed in blue is congruent, while "blue" text displayed in red is incongruent). Participants were instructed to respond to each stimulus by indicating the colour of the displayed text using a letter combination. A total of 40 stimuli were administered during the task. Feedback was provided to participants upon completion of the task through the calculation of the Stroop effect score, which represents the average reaction time of congruent trials subtracted from incongruent trials and is measured in milliseconds.

Following the pre-test phase, the experimental group commenced their intervention, which was integrated into the psychology of art course. This intervention spanned 2 hours, twice a week, over the course of 7 consecutive weeks. The content of the intervention centred on presenting key art historical movements, including the Renaissance, Baroque, Rococo, Romanticism, Impressionism, Cubism, Realism, Art Nouveau, Modernism and Postmodernism. Each artistic movement was explored through the analysis of 3 to 5 works, which were collectively examined by the group within the framework of methodological considerations regarding visual thinking strategies. Following the analysis of each artwork, participants engaged in brief periods of individual reflection before collectively discussing their observations and responses for 5 to 15 minutes per artwork. During the intervention, participants were introduced to VTS methods.

After the intervention phase, both the experimental and control groups underwent reassessment, separated by several days. The reassessment encompassed stimulus preference sequences and computerised cognitive tests, with participants in both groups receiving identical instructions and tasks as those administered during the pre-test phase. It is important to note that the control group did not undergo any post-test intervention.

Based on speculative research in neuropsychological imaging, we examined the cortical electrical neuron activity of four participants during a traditional visual inhibition task conducted using the Emotiv BCI (brain–computer interface) and Emotiv LABS software with the Emotiv Epoc X headset. The algorithm captured both task progression and real-time brain activity. The study encompassed the following sensory areas: FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8 and AF4, with electrode placement following the international 10–20 electrode standard. The EEG resolution was as follows: LSB = 0.51μV (14-bit mode), 0.1275μV (16-bit mode) and bandwidth ranged from 0.16 to 43 Hz. Raw channel data were processed using artificial intelligence, and upon task completion, performance metrics were computed, including engagement level, cognitive stress, attention, reaction time and accuracy. All metrics, except for reaction time, were quantified on a 100-point scale.

Research design

A quasi-experimental non-equal group pre-test–post-test design was used in the study. Data were gathered prior to, during, and following the intervention; the groups were not assigned at random; and the control group did not receive the intervention at the follow-up.

Data analysis

SPSS version 27 was used to process the data. Mean values, standard deviation, minimum, maximum, skewness and kurtosis indices, boxplots and visual inspection of histograms were among the tools used in descriptive data processing. Repeated measures ANOVA was used to test the hypotheses, which assessed the difference in the means of the two groups at three different time points.

Results

We used repeated measures ANOVA to examine the effect of the intervention on executive functions along the two groups. The first condition of the repeated measures analysis of variance was met for the dependent variables, the functions were assessed on a ratio scale. The second condition was also met, there were two groups with three repeated measures. The fourth criterion of normal or near-normal distribution, with logarithmic correction, was met.

The assumption of sphericity was evaluated using Mauchly's Test. The results indicated that the assumption of sphericity was not violated, χ^2 (2) = .88, p >.05. The effect of time along the Flanker effect was not significant, F(2.80) = 1.04, p >.05, ηp^2 = .02. The group effect was not found to be significant, F(1.40) = 4.00, p >.05, ηp^2 = .09. The interaction effect

Table 2: *Means, standard deviation and repeated measures analysis of variance results*

Variable	*Experimental*		*Control*		*ANOVA*			
	M	SD	*M*	SD	Effect	*F* ratio	df	η_p^2
Flanker effect								
Time 1	–.01	.05	.03	.05	G	4.00	1	.09
Time 2	.01	.04	.02	.04	T	1.04	2	.02
Time 3	.03	.04	.02	.03	G × T	4.29*	2	.09
Stroop effect								
Time 1	.03	.04	.01	.05	G	.51	1	.01
Time 2	.04	.04	.03	.09	T	2.35	2	.05
Time 3	.04	.04	.05	.04	G × T	.87	2	.02

Note: N = 42. ANOVA = analysis of variance; G = Group;
T = Time; G × T = Group × Time. *p <.05.
Source: Compiled by the author.

of the time*group was found to be significant with a medium effect size, $F(2.80) = 4.29$, $p < .05$, $\eta p^2 = .09$. The reaction time of the experimental group (M = .03, SD = .04) was slower after the intervention than that of the control group (M = .02, SD = .03).

The assumption of sphericity was evaluated using Mauchly's Test. The results indicated that the assumption of sphericity was not violated alongst the Stroop effect values, χ^2 (2) = .64, p >.05. The time effect is not significant, $F(2.80) = 2.35$, $p > .05$, $\eta p^2 = .05$. There is no significant effect of group, $F(1.40) = .51$, $p > .05$, $\eta p^2 = .01$. No significant interaction effect was found for the time*group effect, $F(2.80) = .87$, $p > .05$, $\eta p^2 = .02$. Following the intervention, there was no significant difference in the experimental group's (M = .04, SD = .04) and control group's (M = .05, SD = .04) reaction times (Table 2).

We used repeated measures ANOVA to examine the effect of the intervention on preference score along the two groups. The non-significant result of Mauchly's Test of Sphericity, $\chi 2$ (2) = .92, p >.05, suggests that the assumption of sphericity was upheld in the analysis of preference scores for visual stimuli. The time effect was significant with a large effect, $F(2.80) = 8.03$, $p < .01$, $\eta p2 = .16$. The group did not show a significant effect, $F(2.40) = 0.00$, $p > .05$, $\eta p2 = .00$. The interaction effect for time*group was found to be not significant, $F(2.80) = 1.46$, $p > .05$, $\eta p2 = .03$ (Table 3).

In a further analysis we investigated the electrical brain activity of experts (N = 2) and novices (N = 2) in visual arts. EEG results suggest functional differences between experts and novices, these results are only orientational (Table 3).

Table 3: *EEG results of visual inhibitory task*

	Art experts		*Non-artists*	
	1	2	3	4
Variables				
Accuracy	99	88	100	87
Reaction time	374	380	381	388
Cognitive stress	30	30	48	62
Attention	53	59	44	52
Involvement	50	51	51	59

Note: N = 4

Source: Compiled by the authors.

Discussion

In the present study we investigated the impact of the VTS method on visual stimulus preferences and executive functions. Our results revealed that there is a statistically significant effect for time on stimulus preference. This suggests that there was a change in Stimulus preference across the three different time periods. The main effect for time was significant. The value obtained for time in this study suggests large effect size. However, our results also revealed no statistically significant differences in stimulus preference between the two groups, suggesting no effectiveness of the intervention. This result can also be interpreted as a consequence of mere exposure effect (Zajonc 1968; Bornstein – Craver-Lemley 2022).

Regarding the influence of the VTS method on executive functions, our results indicate no differences between the two groups across time periods in Stroop effect. This result can be interpreted as being influenced by the effect of cognitive fatigue, as discussed by Junior et al. (2020), in both groups.

Data analysis revealed statistically significant interaction effect between time periods and groups, with a medium effect size on flanker task results. The reaction time (RT) of the experimental group was slower compared to the RT of the control group, suggesting greater flanker effect on the experimental group. This result partially is in line with previous study results. The results from the study of Mikneviciute et al. (2023) revealed flanker effect growth over time periods as a result of acute stress effect. While stress was not directly addressed in this study, given the timing of the last measurement (the week before the exam period began) and the nature of the VTS instructions, which involve response delay to stimuli, it can be inferred that these factors contribute to the observed increase in the flanker effect within the experimental group.

The result of the EEG study indicates differences between art experts and non-artists regarding the measured variables that suggests functional differences between the level of expertise. Despite the differences in the reaction time, these results are only orientational and qualitative, thus further investigation are needed for generalisable conclusions.

Limitations

One major limitation of this study is the data collection process; although participants completed tasks individually, they were seated in a group setting. Another limitation stems from the inconsistency in the literature, as there is a lack of consensus regarding the definition of executive functions.

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