Visual Noise and Cognitive Overload in Online Education: A Hidden Barrier for Pupils with Executive Function Disorders

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ABSTRACT

Aim. This study examines the effect of visual noise in online learning interfaces on cognitive load and task performance among pupils with executive function disorders (EFD).

Methods. The study involved 86 Ukrainian pupils aged 10–14 diagnosed with executive function difficulties. Participants completed structured online learning tasks under two interface conditions: minimalist and visually overloaded. Cognitive load was assessed using the NASA-TLX scale, while performance was evaluated through task accuracy and completion time. Quantitative data were analysed using independent samples t-tests and effect size calculations, complemented by thematic analysis of qualitative responses.

Results. Visually overloaded interfaces produced significantly higher cognitive load scores, lower task accuracy, and longer completion times than minimalist interfaces ($p < .001$). Qualitative findings additionally revealed recurring patterns of sensory overstimulation, cognitive fatigue, reduced motivation, and task avoidance.

Conclusion. The findings support Cognitive Load Theory by demonstrating that excessive interface complexity exacerbates cognitive overload and negatively affects task performance in pupils with EFD. The study concludes that cognitively optimised interface design represents an essential condition for inclusive digital education.

Research restrictions. The study was limited to pupils from a single regional context and did not perform subgroup comparisons across different EFD profiles.

Cognitive value. The research provides empirical evidence on the relationship between interface complexity and cognitive overload in neurodiverse learners and contributes to the development of evidence-based inclusive design principles for digital education.

Keywords: cognitive load, executive functions, online education, inclusive design, visual noise

Introduction

The digital transformation of education has become a defining vector of reform in both post-pandemic and wartime contexts. Schools and universities are increasingly adopting online platforms that are promoted as tools for ensuring flexibility, accessibility and adaptability of learning processes. However, despite the declared inclusivity of digital education, the actual accessibility of such interfaces for pupils with neurodiverse profiles remains limited.

In particular, pupils with executive function disorders (EFD) – including deficits in attention, difficulties with working memory and cognitive inflexibility – encounter barriers that stem less from the content of learning and more from the visual organisation of the digital environment. A key obstacle is visual noise: redundant or unfocused visual information (such as animated elements, highly saturated colour schemes or fragmented navigation) that induces cognitive overload, thereby reducing engagement, impairing comprehension and diminishing motivation.

The theoretical framework of this study is grounded in Cognitive Load Theory (CLT), originally proposed by John Sweller (1988) and further elaborated by Richard E. Mayer and Roxana Moreno (2003). CLT distinguishes between three types of load: intrinsic (inherent to the complexity of the material), extraneous (arising from the mode of presentation) and germane (supporting schema construction). For pupils with EFD, extraneous load – particularly that generated by visual noise in interfaces – poses the most significant risk, as it competes with limited cognitive resources without contributing to learning. In online education, where the visual channel is dominant, such extraneous load critically undermines attention regulation, working memory and cognitive flexibility.

Although theoretical models of cognitive load and inclusive design principles (Heasman & Gillespie, 2018) are well established, empirical investigations into how interface complexity affects school-aged pupils with EFD remain scarce, particularly in Central and Eastern European contexts. This gap creates a research niche for interdisciplinary analysis combining cognitive psychology, inclusive pedagogy and educational technology.

Accordingly, the present study aims to examine how visual noise in digital learning interfaces influences cognitive load in pupils with executive function disorders. It employs a mixed-methods design – integrating experimental testing and qualitative interviewing – through the comparison of two interface prototypes with systematically varied levels of visual complexity.

Literature Review

The role of visual design in educational environments for neurodiverse learners has been increasingly examined within cognitive pedagogy, inclusive design and educational technology (EdTech). Cognitive Load Theory (CLT) (Paas et al., 2003) emphasises that the structure and presentation of information environments can substantially increase or reduce the load on working memory. This issue becomes particularly critical when learners exhibit executive function impairments such as difficulties in sustaining attention, cognitive flexibility or planning.

Mayer and Moreno (2003) demonstrated that visual noise – an excess of visual or multimedia elements – elevates cognitive overload and hinders the retention of educational material. More recent research has extended these insights to digital learning platforms. For instance, Sabine Seufert et al. (2021) reported that students with weaker executive capacities performed significantly worse when interacting with visually complex interfaces compared with their neurotypical peers.

Structured visual organisation of interfaces has also been shown to reduce cognitive load for users with attention difficulties. Sophie Forster et al. (2014) found that enhancing perceptual structure improved concentration in adolescents with ADHD, thereby supporting focus and improving learning outcomes. Similarly, Florence Martin et al. (2020) demonstrated that specific features of learning management system (LMS) design directly affect self-regulation processes among students with executive function difficulties.

The concept of Universal Design for Learning (UDL) further advances this line of research. UDL advocates the creation of educational environments that inherently account for learner diversity. Kavita Rao et al. (2014) argue that interface adaptation is a critical component of digital inclusion and that neglecting visual complexity constitutes a hidden form of discrimination. Brunilda Zenelaga et al. (2024) similarly highlight the role of inclusive practices at the university level in reducing exclusion risks.

Despite these theoretical advances, empirical studies directly measuring the impact of visual noise in digital platforms on pupils with executive function disorders remain limited – particularly within school-age populations. This gap defines a clear research niche for applied investigation, the findings of which may inform EdTech development, classroom practice and state-level inclusive education policy. The urgency of developing inclusive digital learning communities is also underscored by Klodiana Leka et al. (2024).

Theoretical Framework

This study adopts an interdisciplinary perspective that integrates cognitive psychology, inclusive pedagogy and the design of digital learning environments. The theoretical foundation is provided by Cognitive Load Theory (CLT), which explains how the mode of information presentation shapes learning efficiency. First proposed by Sweller (1988) and later extended by Mayer and Moreno (2003), CLT distinguishes three types of cognitive load: intrinsic (arising from the complexity of the material), extraneous (caused by the form of presentation) and germane (supporting knowledge construction). Among these, extraneous load – particularly that generated by excessive visual elements or visual noise – poses the greatest risk in digital learning environments, especially for pupils with executive function disorders (EFD).

EFD encompasses dysfunctions in core cognitive mechanisms such as working memory, cognitive flexibility and inhibitory control, which regulate the capacity to sustain attention, plan and execute tasks sequentially (Diamond, 2013). Pupils with EFD are therefore highly sensitive to visual overload, which may trigger attention lapses, impulsivity or even complete disengagement when interacting with interfaces saturated with graphics, animations, bright colours or fragmented navigation structures. Empirical evidence from Seufert et al. (2021) confirms that it is often the design of the learning environment – rather than its content – that determines cognitive fatigue and reduced performance in neurodiverse groups.

The Universal Design for Learning (UDL) framework plays a pivotal role in this context. Emerging from inclusive education practices and further advanced in digital pedagogy projects, UDL emphasises the creation of learning environments that are designed from the outset to accommodate diverse cognitive profiles. According to the model proposed by CAST and elaborated by Rao et al. (2014), UDL requires digital platforms to provide predictable, visually calm interfaces with clear hierarchies, limited distracting elements and built-in adaptability. Such characteristics minimise extraneous load and promote stable learner engagement. This aligns with findings from Andriana Shyshak et al. (2024), who emphasise the importance of digital safety and self-regulation among younger school pupils.

Synthesising these perspectives, the study frames visual noise in learning management system (LMS) interfaces as an independent variable that indirectly affects learning outcomes through subjective cognitive load. This conceptualisation allows an empirical test of whether differences in interface complexity influence not only information processing but also the behavioural and emotional responses of pupils with EFD, thereby identifying pedagogically significant principles for the design of inclusive digital environments.

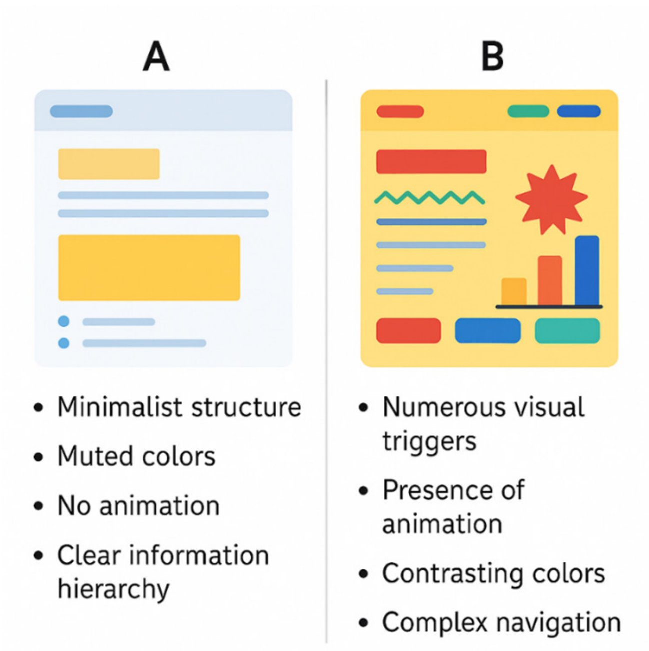
Methodology

The methodological design of this study was guided by the need to empirically verify the hypothesis that visual noise in online learning interfaces increases cognitive load and reduces learning performance among pupils with executive function disorders (EFD). To address this aim, a mixed-methods approach was adopted, integrating quantitative measures (subjective load ratings, task completion time, accuracy) with qualitative insights into pupils' emotional and behavioural experiences. This design enabled the identification of not only objective effects of interface design but also subjective cognitive–emotional responses in neurodiverse learners.

The experiment was based on an A/B comparison model, where each pupil interacted with two versions of a digital learning environment. The minimalist interface (Condition A) was designed according to the principles of cognitive minimisation: a single-column layout, a calm colour palette, a clear visual hierarchy and the absence of animations. By contrast, the overloaded interface (Condition B) deliberately included features associated with visual noise – bright backgrounds, decorative inserts, moving elements and non-intuitive navigation. Both versions were developed using established principles of cognitive ergonomics (Mayer & Moreno, 2003) and UX design adapted to neurodivergent profiles. A visual comparison of key interface characteristics is provided in Figure 1.

Figure 1

Visual Typology of Interfaces in Conditions a and b According to Cognitive Ergonomics Parameters



Source. Own research.

These parameters formed the basis for the research hypothesis, namely that structural interface complexity directly increases cognitive load. The hypothesis was tested in an experimental setting with a total sample of 86 pupils aged 10–14 years, all with clinically confirmed neuropsychological diagnoses affecting executive functions. The sample included: 28 with attention deficit hyperactivity disorder (ADHD), 14 with working memory dysfunction, 8 with mixed-type impairments, and 4 with mild autism spectrum disorders without intellectual disabilities. Diagnoses were established by school psychologists or neurologists using standardised protocols (DSM-5/ICD-10). Screening and initial assessment employed the Behaviour Rating Inventory of Executive Function – Second Edition (BRIEF-2, parent version) as well as selected NEPSY-II subtests focusing on working memory and attentional control. Participants were recruited according to relevance of diagnosis, prior experience of online learning, and parental consent, with full consideration of ethical standards for research involving minors. Due to incomplete NASA-TLX and task accuracy records, the final quantitative analysis was conducted on 60 pupils (30 per interface condition), with 26 cases excluded because of missing or unusable data.

The experimental task in each condition consisted of a short educational module (text–visual material with an accompanying task) aligned with the school curriculum in the humanities. After completing the module in both interfaces, participants rated their subjective cognitive load using an adapted version of the NASA Task Load Index (NASA-TLX; Hart & Staveland, 1988). They also took part in a brief semi-structured interview exploring emotional, behavioural and motivational reactions to interface design. The order of conditions was counterbalanced to minimise sequencing effects.

The procedure was conducted individually, either at school or at home under remote supervision, following both safety and ethical requirements. Before the task, pupils received oral instructions, a demonstration of the interface and a visualised step-by-step guide. All stages of interaction were documented, including task duration, number of errors and navigation pauses. With parental permission, video segments were analysed to support qualitative interpretation of behavioural patterns.

Quantitative data was analysed using independent samples t-tests to assess differences between the two interface conditions, with effect sizes calculated using Cohen's d. Qualitative interview responses were subjected to thematic analysis, organised into semantic clusters (cognitive fatigue, visual disorientation, reactive frustration, reduced interest).

The study adhered to the ethical principles of the Declaration of Helsinki, with written informed consent obtained from parents and verbal assent from pupils. Data was anonymised, emotional comfort safeguarded and the right of withdrawal without explanation upheld. Special attention was paid to ensuring that the procedure was comprehensible, predictable and adapted to pupils' cognitive characteristics.

Thus, the methodology combines experimental rigour with pedagogical empathy, which is critical for assessing the inclusivity of digital learning environments in the context of neurodiversity.

Results

The empirical phase of the study produced data confirming the hypothesis that visual noise in educational interfaces negatively affects both cognitive load and task performance in pupils with executive function disorders (EFD). The analysis of results is presented across three interrelated dimensions: (a) subjective perceptions of cognitive load, (b) task performance, and (c) emotional–motivational responses.

Comparative testing with the NASA-TLX scale (Hart & Staveland, 1988) revealed a substantial difference between the minimalist (Condition A) and overloaded (Condition B) interfaces. The mean overall cognitive load score in Condition B reached 72.6

(SD = 8.4), compared to 48.1 (SD = 7.1) in Condition A. An independent samples t-test confirmed that this difference was statistically significant, $t(58) = 10.24$, $p < .001$, with a very large effect size (Cohen's d = 2.82). This indicates a strong influence of visual complexity on cognitive load. Detailed descriptive statistics for NASA-TLX scores are provided in Appendix (Table A1), and supplementary inferential results are presented in Appendix (Table A3).

Performance outcomes further substantiate these findings by illustrating their behavioural implications. The mean task completion time in Condition A was 7 minutes 42 seconds (SD = 1:02), whereas in Condition B it increased to 10 minutes 16 seconds (SD = 1:34), indicating reduced processing efficiency under conditions of visual overload. Accuracy also declined significantly, from 89.4% in Condition A to 75.1% in Condition B, representing a reduction of 14.3%, which reflects a deterioration in task execution quality rather than merely increased task duration. Extended descriptive results for task accuracy are reported in Appendix (Table A2), while the corresponding inferential analysis is summarised in Appendix (Table A4). A summary of the core quantitative findings is presented in Table 1.

Table 1

Comparative Indicators of Cognitive Load and Task Performance Across Interface Conditions

Measure	**Interface A (minimalist)**	**Interface B (visually overloaded)**	**p-value**	**Cohen's d**
Overall cognitive load (NASA-TLX)	48.1 (SD = 7.1)	72.6 (SD = 8.4)	< .001	2.82
Task completion time (min:sec)	7:42 (SD = 1:02)	10:16 (SD = 1:34)	< .001	1.94
Accuracy (%)	89.4 (SD = 3.4)	75.1 (SD = 4.1)	< .001	3.18

N*ote.* The table presents aggregated results for two interface conditions: minimalist (A) and visually overloaded (B). Reported measures include subjective cognitive load (NASA-TLX), task completion time and accuracy. Effect sizes are reported as Cohen's d. All differences between conditions were statistically significant.
Source. Own research.

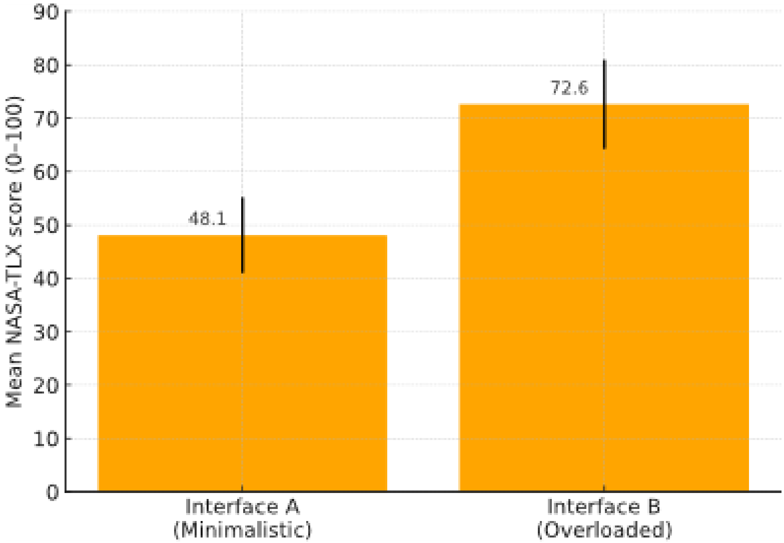
As shown in Table 1, all indicators provide robust evidence of heightened cognitive load and reduced task performance efficiency in the visually overloaded interface, with consistently large effect sizes across all measured variables. This empirically supports the hypothesis regarding the detrimental effects of excessive visual stimulation on students with executive function disorders.

These results collectively indicate that visual overload simultaneously impairs both the efficiency (time) and accuracy of task performance, confirming the systemic impact of interface complexity on cognitive and behavioural outcomes.

The distribution of cognitive load levels is illustrated in Figure 2.

Figure 2

Mean Cognitive Load (NASA-TLX) Across the Two Interface Conditions



Note. The bars represent mean values of subjectively assessed cognitive load; error bars indicate standard deviations. Numerical values and statistical test results are reported in Table 1.

Source. Own research.

These quantitative observations were corroborated qualitatively. Thematic analysis of the interviews revealed four dominant themes that consistently emerged in students' responses following interaction with the overloaded interface. These encompassed sensory overstimulation, cognitive fatigue, reduced motivation, and task avoidance – behavioural patterns typically associated with learners with executive function disorders. The summarised findings are presented in Table 2.

Table 2

Thematic Analysis of Student Interviews Following Interaction with the Overloaded Interface

Theme	Representative quotation	Cognitive interpretation
Sensory overstimulation	"I couldn't concentrate; everything was flashing, and I felt lost even before starting the task."	Excessive visual stimuli hinder attentional focus in neurodiverse learners.
Cognitive fatigue	"By the second screen I was already tired; my brain felt like it had 'frozen' and didn't want to think."	Manifestation of executive function exhaustion triggered by complex visual patterns.
Reduced motivation	"I felt it was too difficult, and I didn't want to continue at all."	Decline in intrinsic motivation caused by perceived overload and a sense of inefficacy.

Theme	Representative quotation	Cognitive interpretation
Task avoidance	"I just clicked everything randomly to finish somehow."	Development of maladaptive strategies due to impaired cognitive control.

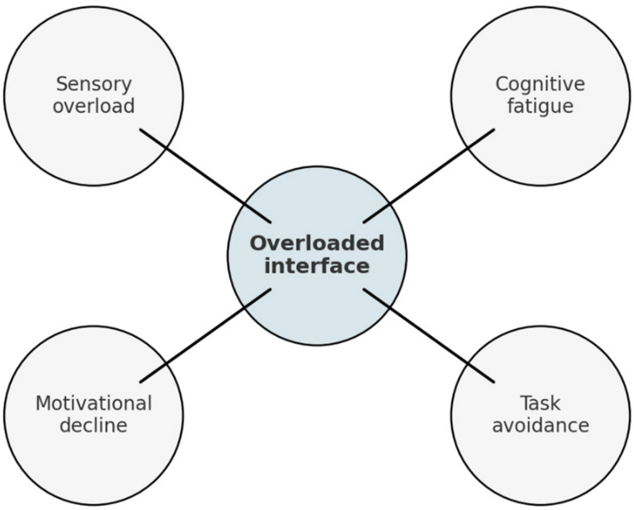
S*ource.* Own research.

As shown in Table 2, respondents most frequently described sensory difficulties, such as feelings of overload caused by excessive visual elements, loss of focus, and inability to concentrate. Cognitive fatigue was also frequently reported, alongside the adoption of maladaptive strategies such as random clicking or task avoidance. Comparable effects of emotional states on learning activity are confirmed by Frantisek Petrovic et al. (2024), who examined the relationship between anxiety, depression, and academic performance in students.

These findings conceptually align with contemporary models of executive dysfunction in the context of digital interaction (Ding et al., 2024; Terras & Ramsay, 2012) and underscore the need for adaptive educational resource design that is responsive to neurodiversity. A visual summary of the qualitative analysis is presented in Figure 3.

Figure 3

Themes from Interviews Identified in Responses of Students with Executive Function Disorders after Interacting with the Overloaded Interface



Source. Own research.

As illustrated in Figure 3, the four dominant themes – sensory overload, cognitive fatigue, reduced motivation, and task avoidance – form a coherent semantic structure describing impaired self-regulation and diminished learning efficiency. The interrelationships between these themes indicate that cognitive fatigue frequently mediates between sensory overload and maladaptive behaviour. Similar psycho-emotional barriers have been reported by Roman Králik et al. (2023) in studies of students in the post-COVID-19 context.

This clustered representation corresponds with contemporary approaches in neuropsychology and cognitive pedagogy, which highlight the systemic interplay of stimuli, emotional responses, and executive functions in children with neurodiverse profiles (Chrysaitis & Seriès, 2023; Pellicano & Burr, 2012).

The following subsection presents a more detailed account of the main semantic categories, clarifying how visual complexity influences emotional state, motivation, cognitive fatigue, and strategic behaviour.

Qualitative thematic analysis of the interviews revealed four recurrent themes that consistently appeared in students' responses after interacting with the overloaded interface:

- Cognitive fragmentation – learners frequently described their impressions as "chaotic" or "scattered," reporting "difficulties with focusing" and "inability to find what was needed in time."
- Emotional frustration – respondents used expressions such as "very irritating," "confusing," and "I did not want to continue."
- Motivational decline – some participants reported reduced willingness to complete the task or to continue learning in such an environment.
- Navigational uncertainty – several students reported difficulties in locating tasks or expressed a need for external assistance (e.g., from teachers or parents).

These themes demonstrated a high degree of recurrence and manifested irrespective of task order, underscoring the stability of the phenomenon whereby interface complexity undermines students with executive function disorders. In contrast, after engaging with the simplified interface, participants more frequently offered positive or neutral evaluations such as "convenient," "easy to understand," or "nothing unnecessary."

It is important to note that although the results are presented in summarised form, all quantitative differences were statistically significant, and the qualitative findings coherently reinforced the quantitative outcomes. A comprehensive overview of all quantitative findings is available in Appendix. Such methodological convergence provides strong evidence for the reliability of the empirical pattern: visual noise functions as a critical factor that disrupts cognitive stability and focus in students with neuropsychological vulnerabilities.

Discussion

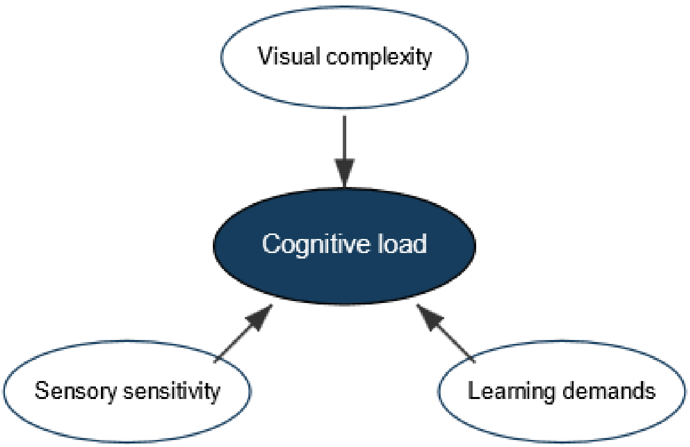
The findings empirically substantiate the central hypothesis that visual noise in digital educational interfaces substantially increases the cognitive load of students with executive function disorders, diminishes their performance, and precipitates emotional frustration alongside disorganisation of the learning process. These results are consistent with earlier theoretical models (Mayer & Moreno, 2003; Sweller, 1988), while extending their applicability to the domain of inclusive digital learning, particularly for neurodivergent users.

First, the differences observed in subjective cognitive load between the "clean" and "overloaded" interface conditions were not only statistically significant but also characterised by a large effect size. This demonstrates that interface complexity operates as an independent variable capable of determining learning outcomes. Such a conclusion is consonant with Seufert et al. (2021), who recorded similar effects among students with varying working memory capacities. The present study, however, shifts the focus towards learners with pre-existing impairments in cognitive regulation, thereby underscoring its pedagogical relevance.

The empirical evidence further corroborates a consistent relationship between excessive visual stimulation, cognitive fatigue, and maladaptive behaviour in students with executive function disorders. These effects are interlinked, manifesting in both reduced motivation and disrupted self-regulation. A schematic representation of these relationships is provided in Figure 4.

Figure 4

Causal Relationships Between Visual Load, Cognitive Fatigue, and Behavioural Maladaptation in Neurodiverse Students



Note. The diagram illustrates the sequential process whereby visual overload in digital interfaces triggers heightened cognitive fatigue, which in turn mediates behavioural maladaptation and reduced self-regulation. The model underscores the cascading impact of interface complexity on learning outcomes, reflecting the systemic nature of executive dysfunction in neurodiverse learners.
Source. Own research.

As shown in Figure 4, sensory overload induced by visually complex interfaces initiates a cascade of effects ranging from cognitive fatigue to avoidance strategies. Kateřina Valachova et al. (2023) likewise demonstrated that overload and stress reduce performance and contribute to exhaustion in professional contexts. A decline in cognitive control reinforces maladaptive responses, undermines motivation, and increases the likelihood of educational disengagement. The model illustrates the multicomponent influence of interface-induced cognitive load, consistent with contemporary theories of executive dysfunction (Diamond, 2013; Sweller, 1988).

Secondly, the qualitative data gathered through semi-structured interviews revealed the semantic depth of emotional responses that often elude conventional quantitative approaches. Affective markers such as irritation, fatigue, discouragement, and deliberate withdrawal from tasks indicate that visual complexity affects not only cognitive but also emotional–behavioural dimensions of executive functioning. These findings suggest that learning barriers for students with executive function disorders are multidimensional and cannot be reduced solely to deficits in attention or memory.

Importantly, in this study executive functions are conceptualised not merely as cognitive processes but as adaptive mechanisms that integrate affective regulation and motivational dispositions. Behavioural patterns reported by participants (e.g., spontaneous task withdrawal, emotional disorientation) exemplify the interplay between sensory overload, frustration, and impaired self-regulation. This interpretation accords with an extended definition of executive dysfunction that encompasses motivational and emotional dimensions (Diamond, 2013).

Additionally, analysis of NASA-TLX subscales revealed that the dimensions most sensitive to interface overload were mental demand, frustration level, and effort, whereas performance remained comparatively stable. Statistically significant differences ($p < .05$) between Conditions A and B on the mental demand and frustration subscales support the hypothesis of heightened extraneous cognitive load in the overloaded interface. Particularly noteworthy was the increase in frustration, which in Condition B averaged 70–75 points on the NASA-TLX scale, exceeding the recognised threshold of emotional maladaptation (Hart & Staveland, 1988).

These results align with contemporary approaches to analysing affective load in digital learning environments (Peng et al., 2021). In the present case, however, they are directly linked to specific parameters of interface design, thereby enabling the localisation of maladaptation triggers at the level of user interface solutions.

Thirdly, the findings have important implications for inclusive UX design, which remains insufficiently embedded in mainstream educational platforms. Despite the availability of general recommendations for reducing cognitive overload (Clark & Mayer, 2016; Mayer, 2009), widely adopted tools in school practice (e.g., Google Classroom, Moodle) frequently contain configurations that neglect the requirements of learners with neuropsychological differences. As emphasised by Rao et al.(2014), Universal Design for Learning (UDL) must extend beyond content and pedagogy to encompass the digital environment itself, which is often overlooked by educational developers.

It is essential to acknowledge, however, that while the consistency of the present findings is encouraging, they also give rise to questions that extend beyond the current analysis. Future research should explore the relationship between specific types of executive function disorders (e.g., deficits of selective attention versus working memory impairments) and the particular triggers of interface-induced overload. Equally, the cultural and educational context warrants further consideration: visual standards shaped by national schooling traditions may influence perceptions of complexity and the tolerance thresholds of learners.

In summary, this study broadens the scope of contemporary inclusive pedagogy by demonstrating that the structural design of digital learning environments is not a neutral technical feature but a powerful determinant of inclusion or exclusion. In light of ongoing strategies for the digitalisation of education, these findings should inform a revision of the principles of digital inclusivity, not only at the level of classroom practice but also within national educational policy. This conclusion resonates with Hedviga Tkacova and Martina Pavlikova (2024), who emphasise the role of social media and targeted interventions in supporting young people navigating the challenges of digital environments.

Limitations and Future Research Directions

While this study provides robust evidence of the impact of visual noise in digital learning environments for pupils with executive function disorders (EFD), several limitations should be acknowledged. First, the sample size was relatively modest and limited to middle school pupils, which constrains the generalisability of the findings across different age groups and educational contexts. Second, the study did not differentiate between subtypes of executive dysfunction (e.g., selective attention deficits versus working memory impairments), which may influence the degree of sensitivity to interface complexity. Third, cultural and aesthetic expectations regarding interface design were not systematically controlled, suggesting that regional or contextual norms may have shaped participants' subjective responses. Finally, reliance on self-reported cognitive load and qualitative interviews, while informative, may not fully capture the underlying neurocognitive mechanisms of overload.

Future research should address these limitations by conducting larger-scale studies with stratified samples that distinguish between specific EFD profiles. Cross-cultural comparisons could provide valuable insights into how visual standards and digital literacy norms mediate perceptions of interface complexity. Furthermore, the integration of physiological and neurocognitive measures, such as eye-tracking or EEG, would complement self-report instruments and yield a deeper understanding of attentional and affective responses. Finally, longitudinal studies are needed to assess the enduring effects of inclusive interface design on learning engagement, academic performance, and emotional well-being in neurodiverse populations.

Conclusions and Practical Implications

The findings confirmed the central hypothesis that visual overload in digital educational interfaces exerts a detrimental impact on both cognitive functioning and behavioural adaptation in students with executive function disorders (EFD). Quantitative indicators (NASA-TLX ratings and task performance) demonstrated statistically significant differences between low- and high-complexity interface conditions, underscoring the decisive role of interface design in shaping cognitive load. Complementing these results, the qualitative analysis revealed affective and motivational markers of frustration, avoidance, and fatigue, thereby illustrating the multidimensional nature of barriers in digital learning for neurodivergent learners.

The interpretation of these findings positions the structural design of educational interfaces not as a neutral technical factor but as a critical determinant of inclusivity within digital learning environments. The application of Universal Design for Learning (UDL) principles should therefore extend beyond content and pedagogy to encompass the visual–semiotic structure of digital platforms. This consideration is particularly relevant for widely adopted school-level tools used in blended and distance education, where design-related cognitive barriers may heighten the risks of exclusion for learners with diverse neurocognitive profiles.

From a practical perspective, the findings provide actionable insights for UX design strategies in educational platforms, supporting the development of calmer, more predictable, and adaptive interfaces tailored to the needs of neurodivergent learners, particularly in distance and hybrid learning contexts.

From a policy perspective, the study underscores the necessity of embedding digital inclusivity within educational regulations and standards. These findings align with the priorities articulated in the EU Digital Education Action Plan (2021–2027) and the UNESCO Guidelines for Digital Education (2023/2024), both of which emphasise the reduction of cognitive barriers and the adoption of universal design principles. Incorporating such frameworks into national education policies can help ensure that neurodiverse learners are not excluded from the benefits of digital transformation.

Looking ahead, the findings provide a foundation for the development of adaptive, neurosensitive educational platforms tailored to individual learning trajectories within inclusive digital ecosystems. Such innovations may not only enhance accessibility but also contribute to the broader agenda of equitable digital education.

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Appendix

Descriptive statistics for study variables

Table A1

Descriptive Statistics of NASA-TLX Scores by Interface Complexity

Variable	N	Min	Max	M	SD	Skewness	Kurtosis
NASA-TLX (Low-complexity)	30	33	62	48.1	7.1	0.18	-0.31
NASA-TLX (High-complexity)	30	58	88	72.6	8.4	0.22	0.12

Source. Own research.

Table A2

Descriptive Statistics of Task Accuracy by Interface Complexity

Variable	N	Min	Max	M	SD	Skewness	Kurtosis
Task accuracy (Low-complexity)	30	84	97	89.4	3.4	-0.16	0.28
Task accuracy (High-complexity)	30	68	88	75.1	4.1	0.20	-0.11

Source. Own research.

Results of statistical tests

Table A3

Independent Samples t-Test for NASA-TLX Scores

Variable	t	df	p	Cohen's d
NASA-TLX (Low vs High complexity)	10.24	58	< .001	2.82

Source. Own research.

Table A4

Independent Samples t-Test for Task Accuracy

Variable	t	df	p	Cohen's d
Task accuracy (Low vs High complexity)	12.87	58	< .001	3.18

Source. Own research.