Playful Modular Robotics Among Children in Kyiv Under Condition of War and Ukrainian Refugees

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Abstract: Wartime is a highly stressful situation. In the context of the war in Ukraine, the chronic stress experienced by children could hinder the learning process but also creativity, which the emotional state of the learner-player can impact. In this study, we evaluated how stressful situations such as war conditions can impact divergent thinking (DT) in creative problem solving (CPS). Different educational contexts support CPS with activities that require learners to engage in creative problem-solving. In e-learning, CPS is expected to support the development of higher-order thinking skills (Setyosari, Kuswandi & Ulfa, 2023) but can be impacted by contextual factors such as chronic stress (Kassymova et al., 2019). This study aims to evaluate a CPS task in the context of the chronic stress of Kyiv learners but also the stress endured by Ukrainian refugees abroad. For this objective, we study three aspects of DT: fluency, flexibility, and originality. We did this by giving Ukrainian participants a CPS robotic task that made them think of ways to come up with new ideas while they were living in France as refugees during a war. We aim to identify how stressful situations affect divergent thinking by comparing these two groups of learner-players in the CPS task. The early results show that the participants from Kyiv, who had lived through almost a year of war, were much more flexible and creative in their DT than the refugee participants in France. This suggests that the stressful environment in Kyiv may have contributed to the development of more original and diverse ideas, possibly due to daily problem-solving activities within war constraints. Playful situations in wartime allowed Kyiv participants to exhibit higher divergent thinking than participants in France. This suggests that wartime constraints may enhance strategies for generating novel ideas while highlighting the positive impact of engaging in game activities on divergent thinking, even in stressful situations.

Keywords: Divergent thinking, Creative problem solving, Creativity, Chronic stress, War

1. Introduction

Over the past decade, there has been an active debate on how the key skills required to fulfil one's potential in the professional field and to live a full life in the modern digital society are changing. In particular, since 2015, analysts at the World Economic Forum (WEF) have been ranking *complex problem solving* skills and *creativity* among the top 10 important skills and competencies. According to the Digital Competence Framework for Citizens (*DigComp 2.2*) problem solving skills are one of the most important parts of Digital Competence for modern humans (European Commission, 2022). The forecasts for 2025 also include these skills (WEF, 2020). According to the Future of Jobs Report 2023 (WEF, 2023), *creative thinking* is the most sought-after skill in the forecasts until 2027. Thus, the need for specialists who are *creative problem solvers* will grow in the coming years.

Creative Problem Solving (CPS) involves breaking down a problem to understand it, generating ideas to solve it, and evaluating those ideas to find the most effective solutions. Osborn originated the CPS approach in the 1940s. Their CPS process has been taught at the International Centre for Studies in Creativity at Buffalo College since the 1950s (Mcdonald, 2019). While CPS has been studied in a diversity of tasks, the analysis of CPS in playful, educational robotics is still limited in creative studies. With this objective, we aim to contribute to supporting the CPS study through the use of educational robotics in order to better identify the CPS processes in the context of chronic stress indeed by the war conditions in Ukraine.

Analysis of similar studies has shown that stressful situations affect learners' educational opportunities and creative thinking. One of the aims of this study was to find out how playful modular robotics affects creativity and whether it can be used to maintain the motivation to learn and creative activity of children in war. The results of such studies will provide recommendations for teaching children in stressful situations and for using this approach for learners in similar situations. In turn, this will minimise educational losses and maintain students' positive motivation to learn.

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2. Creative Problem Solving, Divergent and Convergent Thinking

Creativity is a complex human process that can be observed in a high diversity of learning, professional, and personal tasks. Nowadays, it's acknowledged that creativity is a result of a dynamic interaction of cognitive, affective, and contextual elements. As all these factors are present in human beings and all these variables affect us to a certain degree, it can be argued that a specific combination of them results in creativity (Kanlı, 2020). According to Lubart's (2017) 7C's framework for conceptualising work on creativity, it may take many various forms and encompass a wide range of activities, from the generation and context of ideas and outputs to their consumption.

Different evaluation methods of creativity are described by Kanlı (2020). The author notes that divergent thinking is primarily used in creativity assessment tests to evaluate the creative process. Divergent thinking (DT) is defined by Guilford (1968) as a method of thinking that produces original ideas by considering a wide range of potential answers. Convergent thinking focuses on arriving at the "correct" solution.

CPS is a way of using creativity to develop new ideas and solutions to problems. During CPS tasks, the learner is engaged in divergent thinking (*ideation*) and convergent thinking (*idea selection*) processes in different cycles of iterative improvement (Runco, 2011), Figure 1.

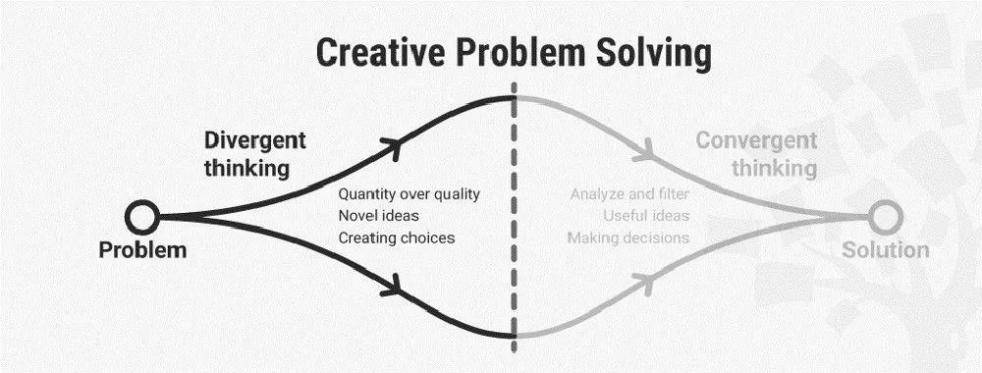

Figure 1: CPS, divergent and convergent thinking (Runco, 2011; IxD, Siang, 2016)

DT represents a cognitive process that results in the generation and exploration of various ideas in diverse directions within problem-solving scenarios. These ideas can range from conventional to original. DT necessitates coming up with several solutions through free-flowing, spontaneous thought, which is a crucial component of CPS (Runco, 2011, 2014). Within CPS, *divergent thinking* is associated with idea generation, and *convergent thinking* is associated with idea selection. Though the results of DT tests have shown to be instructive regarding the potential for CPS, DT is by no means synonymous with creativity. DT assessments provide data on originality, a component of the common definition of creativity, as well as idea fluency and adaptability (Runco, 2022). Guilford (1967) defines the three key components of DT as fluency, flexibility, and originality. DT is non-linear, offering users multiple paths instead of a straightforward route, providing enhanced flexibility, latitude, and a broad array of choices. Differentiating between idea fluency (whether or not an idea is original), idea flexibility (showing how an idea is different from previous ones), and idea originality (showing ideas that are uncommon in a certain reference group) are all possible with DT (Runco, 2022). Originality, as a crucial DT component, holds significant importance as it serves as a prerequisite for creativity (Acar et al., 2019).

In the context of CPS tasks, DT is the process of creating multiple, unique ideas or solutions to a problem that an individual is trying to solve. The assessment results of DT depend not only on the interindividual differences of the person but also on the task and the materiality of the artifacts engaged in the task (Leroy, Romero & Cassone, 2021; Romero & Barma, 2022).

3. Creative Problem Solving Using Playful Educational Robotics Under Stressful Conditions

CPS can be supported with visuospatial constructive play objects (VCPO) or artifacts such as modular robotics (Ness & Farenga, 2016). Educational robotics classes have the potential to support the implementation of interdisciplinary links with STEAM subjects, as well as the practical application of theoretical knowledge. Zhang and Zhu (2022) note the influence of educational robotics on creativity and problem-solving skills with the increasing use of robotics in education. To effectively increase students' creativity and problem-solving skills, educators and researchers should fully utilise its benefits. In the CPS tasks with modular robotics, creativity can

be observed not only by the analysis of the configurations but also by the behavioural learning analytics, including the gestures and actions of the participant engaged with the mediating artifacts (Strutynska & Romero, 2023).

In the present study, we highlight the designers' DT, and the real product generated through the configuration created using a series of modular robotic cubes. We organised CPS tasks by using a game approach with educational robotics. Tang, Vezzani, and Eriksson (2020) concluded the positive impact of the game approach on the development of critical thinking, collective creativity, and problem-solving skills. Our experiment was conducted during the sad and, at the same time, unique experience of teaching and learning during wartime in Ukraine. Children and adults experience many forms of chronic stress during times of war, which can have long-term effects. In this way, we had the unique opportunity to study how stress can impact creativity and CPS. Different research and opinions exist about how stress can impact creativity and CPS. Some researchers studying the impact of stress on creativity indicate that their relationship is controversial because stress can affect creativity either positively or negatively (Table 1).

Table 1: Research and opinions about the impact of stress on creativity and CPS

A positive climate is very important to support CPS	Stinkeste, Napala & Romero (2021)
Stress may boost creative thinking in organisations. Stress is a source of extrinsic motivation and raises arousal levels. When people are under stress, they may utilise a concentrated problem-solving method that promotes creativity	Anderson, De Dreu & Nijstad (2004)
Stress tends to reduce creativity by putting a strain on cognitive abilities, leading to the employment of straightforward cognitive techniques that are likely to decrease originality	Byron, Khazanchi & Nazarian (2010)
Stress and creativity interact ambiguously. On the one hand, stress suppresses creativity, like all other intellectual abilities. On the other hand, stress encourages people to search for new forms of response, i.e., to be creative	Kassymova, Tokar, Tashcheva, Slepukhina et al. (2019)
Individuals in the stress condition generate fewer divergent thinking ideas and fewer problem solutions than individuals in both the cope and relax conditions	Kobe (1999)

It is thought that to be nurtured, creativity needs a happy emotional environment. For example, Stinkeste, Napala, and Romero (2021) demonstrate that a supportive environment is critical to CPS in individual and group contexts. Team environment in STEAM activities has been found to facilitate co-creativity and the creative process. According to Anderson, De Dreu, and Nijstad (2004), stress in the workplace may foster innovative thinking. Their research indicates that stress increases arousal and serves as a source of extrinsic motivation. Because of this, people under stress could apply a focused approach to problem solving that encourages innovation. Other studies show that stress can reduce creativity (Kobe, 1999; Byron, Khazanchi & Nazarian, 2010). According to Byron, Khazanchi and Nazarian (2010) meta-analysis in psychology studies, stress tends to lower creativity by taxing cognitive capacities, which forces the use of simple cognitive strategies that are likely to lessen originality.

In their study, Kassymova et al. (2019) examined the impact of stress on students' health and academic performance. They also discovered that there was an unclear interaction between stress and creativity when they looked into the following dependencies. Stress inhibits creativity in the same way that it does all other intellectual capacities. On the other hand, stress encourages people to search for new forms of response, which is an essential aspect of creative behaviour. The *type of stress* experienced by the subject has a significant impact on how creative someone may be in a stressful scenario. A person's creative achievements are higher and more extensive when they are under more stress. A person's capacity for creativity makes it easier for them to handle stress, sometimes even without realising it. And the necessity for their realisation might put someone in complicated situations due to their creative ability (Kassymova et al., 2019). Thus, a person's creative abilities can be an important source of stress resistance.

3.1 Engaging Youngsters In Creative Problem Solving Activities With Educational Robots Under Conditions of War

Safety is an essential human need for all citizens. Adults and children experience different forms of chronic stress during times of war, and these effects can last for a long period. The literature review shows little research on how war affects learning abilities, creativity, and CPS. The impacts of war on a child's psychological development have been noted in the literature review by Elbedour, ten Bensel, and Bastien (1993), mainly if the adult figures in the child's life have not yet acquired coping mechanisms.

When the war in Ukraine started, we wanted to know how to help Ukrainian colleagues in the learning sciences and support their educational efforts during wartime. One of the study's aims is to determine whether the activities offered to students with modular robotics can contribute to achieving sustainable development goals (SDGs), particularly ensuring equitable and quality education. Université Côte d'Azur's *MSc SmartEdTech program's* research and social values aim to create educational materials that can help achieve the sustainable development goals (SDGs), with a particular emphasis on quality education (SGD4), which aims to "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all". We scheduled our first event for 2021 on Women's Day 2021 and invited female scholars in STEM education from Ukraine to participate in a special webinar. Following that, we got the chance to assist Prof. Oksana Strutynska, a full professor at Kyiv, in her participation in the *Let's STEAM!* and *ANR CreaMaker* initiatives in the LINE research lab. Next, we planned two seminars in Nice, where we supported computer science activities that were unplugged and produced as part of the Unplugged Quest project planned for 2022. Professor Strutynska took a plane back to Kyiv in January 2023 to conduct various one-on-one and group play sessions at the Dragomanov Ukrainian State University's Faculty of Mathematics, Informatics, and Physics.

To engage children in CPS, we offered them a learning task using modular robotics related to generating ideas (actually creating different configurations). Participants must use Cubelets modular robotics to construct an autonomous vehicle that can go from the starting point to the destination. Participants construct a variety of vehicle possibilities (fluency component), innovative ideas (originality component), and diverse concepts (flexibility component). These activities involved Ukrainian participants in a stressful situation, namely in the context of war. To evaluate DT, the students were asked to solve a game task with *CreaCube* (Figure 2). Solving a task with *CreaCube* involves manipulating and stacking cubes.

Figure 2: Cubelets modular robotics

Expanding robotics' application domain and increasing robotics' popularity are hallmarks of the current phase of science and technology development (Buchem & Bäcker, 2022; Chevalier et al., 2022). One aspect of student learning that crosses disciplines is educational robotics. Cybernetics, mechatronics, informatics, digital technology, and STEM (in the STEM area for educational robotics, we focus more on subjects such as physics, technology, and mathematics) are all integrated into its process.

Teaching educational robots enables students of all ages to participate in the process of invention scientific and technological creativity. It aligns with the concept of advanced training (learning the technologies that will be required in the future). Students' technical tendencies may be identified early on, and their technical inventiveness can be developed thanks to the usage of educational robots (Morze, Strutynska & Umryk, 2018; Strutynska et al., 2020). Teaching the younger generation how to build, program, and operate robots and robotic systems is connected to modern needs, such as the rise of new robotics-related occupations and the resulting demand for qualified professionals.

4. Methodology

4.1 Participants

The experiment involved 33 Ukrainian participants, who were divided into two groups: Ukrainian refugees in France and participants from Kyiv who were in the chronic stress situation of war. The participants were presented with a playful activity with modular robotics to evaluate divergent thinking, the *CreaCube* task.

Ukrainian families living in the Nice refugee community were involved in the experiments in 2022. The majority of the kids attend primary and middle schools successfully. Still, their fluency in French varies, necessitating the translation of certain terms, and their level of prior computer science knowledge varies as well. The participants were invited to the LINE lab in Nice. Following the exercises, we shared some snacks to foster teamwork and gave them a chance to reflect on their everyday struggles as well as the Unplugged Quest activities. In Nice, we engaged 17 people in a playful activity in Nice.

The workshops in Nice were organised on a non-school day to allow the parents to come with their children. We shared the Unplugged Quest activities with the parents. They appreciated the language diversity in the activities supporting their children's language learning.

In Kyiv, Prof. Strutynska proposed the participants join the Faculty of Mathematics, Informatics, and Physics at the Dragomanov Ukrainian State University (Ukraine), according to the safety measures during wartime. Participants reported enjoying the playful activities. 16 participants were involved in the experiment. During the workshop, we took all the necessary measures to ensure the safety of the participants. During air raid sirens, we went down to the shelter. After the danger was over, we returned to the game activities (Strutynska & Romero, 2023).

4.2 Evaluation of Divergent Thinking

DT has been thoroughly studied and is considered an important process in creativity research. DT tests are often used in creativity studies and as measures of creative potential (Runco & Acar, 2012; Runco et al., 2016; Acar et al., 2019).

To evaluate divergent thinking, learner-players are asked to solve the CPS *CreaCube* playful task. The resolution of the *CreaCube* activity involves the manipulation and assembly of cubes. To complete the game task, the player must explore unknown cubes and create an autonomous vehicle that can move from the starting point to the final destination using modular robotics (Romero, DeBlois & Pavel, 2018).

Participants are required to build an autonomous vehicle that can move from the starting point to the destination using Cubelets modular robotics. Participants build different options for vehicles (*fluency component*), including different ideas (*flexibility component*) and original ideas (*originality component*). Based on Guilford's operationalization of the Alternative Uses Test (AUT) (1967), we evaluate DT in the *CreaCube* task using the three DT components. *Fluency* corresponds to the total number of distinct ideas; *flexibility* corresponds to the number of distinct categories; and *originality* is the rarest response, corresponding to those provided by fewer than 5% of all participants within the same age category (Strutynska & Romero, 2023). This coding schema permitted the adaptation of Guilford's DT components into the modular robotic task. In this way, we could analyse the process of CPS to evaluate the DT components for every participant.

Participants are invited to play again after their first success in the *CreaCube* game. The purpose of the second attempt is to find out if the player has improved upon and taken into account the cubes' qualities from the previous effort and if they have attempted to solve the problem by coming up with a fresh solution or by trying to replicate the original answer precisely. These subsequent activities also evaluate the participant's DT.

Following the experiments, we scrutinised participants' actions in the videos using custom software featuring pre-set figure configurations (Figure 3).

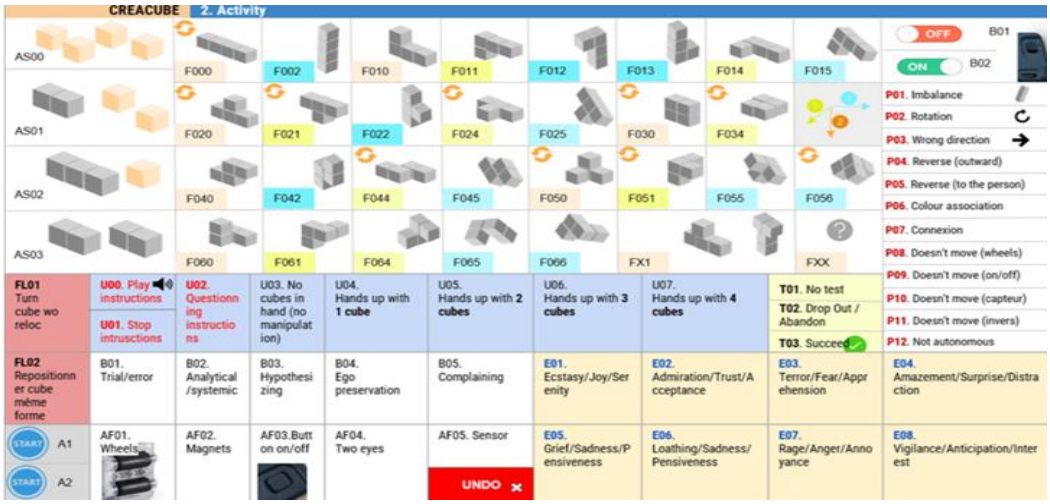

Figure 3: Ad hoc developed software for analysis of DT components

Once the video is uploaded to the *CreaMaker* research platform, it undergoes a comprehensive analysis by integrating specific coding schemas within the framework of behavioural learning analytics. This process allows a meticulous examination of participants' interactions to be coded as unitary events to analyse DT. By systematically decoding the behavioural cues captured in the video, we obtain the indicators for constructing the DT components, including fluency, flexibility, and originality. This analytical approach permits us to understand the participants' cognitive dynamics in the context of CPS with specific observables without subjective evaluations of DT components (Figure 4).

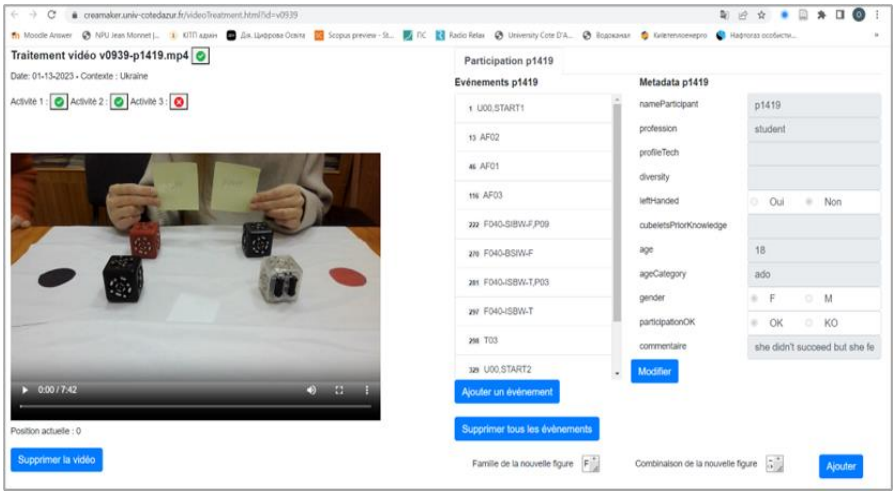

Figure 4: Video analysis using the figures coding schema to calculate the DT scores

5. Results

Throughout the experiments, each learner-player engaged in two rounds of the CreaCube activity labelled A1 and A2. In each iteration, we measured three components of divergent thinking: fluency, flexibility, and originality. The videos were processed using this specially developed software, based on which the DT components are analysed based on the video analysis through the *CreaMaker* platform. The results were analysed using *JASP* (0.17.1 release), Table 2.

Table 2: DT components' scores for Kyiv and Nice participants

	A1_Fluidity		A1_Flexibility		A1_Originality		A1_Time		A2_Fluidity		A2_Flexibility		A2_Originality		A2_Time	
	Kyiv	Nice	Kyiv	Nice	Kyiv	Nice	Kyiv	Nice	Kyiv	Nice	Kyiv	Nice	Kyiv	Nice	Kyiv	Nice
Valid	16	15	16	15	16	15	16	15	14	15	14	15	14	15	14	15
Missing	0	0	0	0	0	0	0	0	2	0	2	0	2	0	2	0
Mean	4.938	4.933	2.188	1.600	1.188	0.133	206.063	223.800	2.857	2.600	1.214	1.200	0.286	0.333	71.000	87.800
Std. Deviation	5.234	8.996	1.974	0.632	1.471	0.352	148.486	227.507	2.381	3.757	0.802	1.265	0.611	0.816	36.574	93.253
Minimum	0.000	1.000	0.000	1.000	0.000	0.000	68.000	64.000	0.000	0.000	0.000	0.000	0.000	0.000	21.000	19.000
Maximum	19.000	37.000	7.000	3.000	5.000	1.000	539.000	655.000	9.000	15.000	3.000	5.000	2.000	3.000	140.000	307.000

We can observe in Table 2 a higher level of flexibility (m = 2.18; sd = 1.97) and originality (m = 1.19; sd = 1.47) in the first instance (*A1*) of the *CreaCube* task among the participants in Kyiv than those in Nice.

The next figures focus on the DT components with the highest differences between the Nice and Kyiv participants. Firstly, figure 3 shows the difference in the first instance of the *CreaCube* activity (*A1*) on the originality DT component. Kyiv participants demonstrate higher levels of originality (m = 1.18; sd = 1.47) compared to their counterparts in Nice (m = 0.13; sd = 0.35). The statistical analysis, utilising Welch's t-test (t(16.821) = 2.784, p = 0.013), indicates a noteworthy and statistically significant difference in originality scores between the Kyiv and Nice groups (Figure 5, Figure 6).

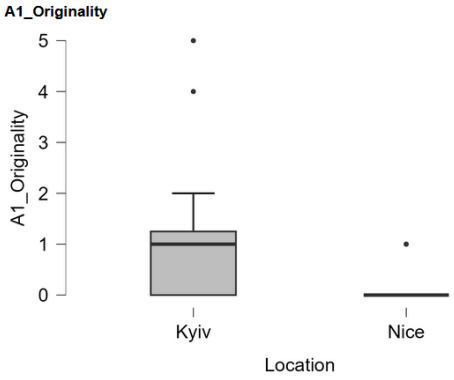

Figure 5: Originality in A1 among Kyiv and Nice participants

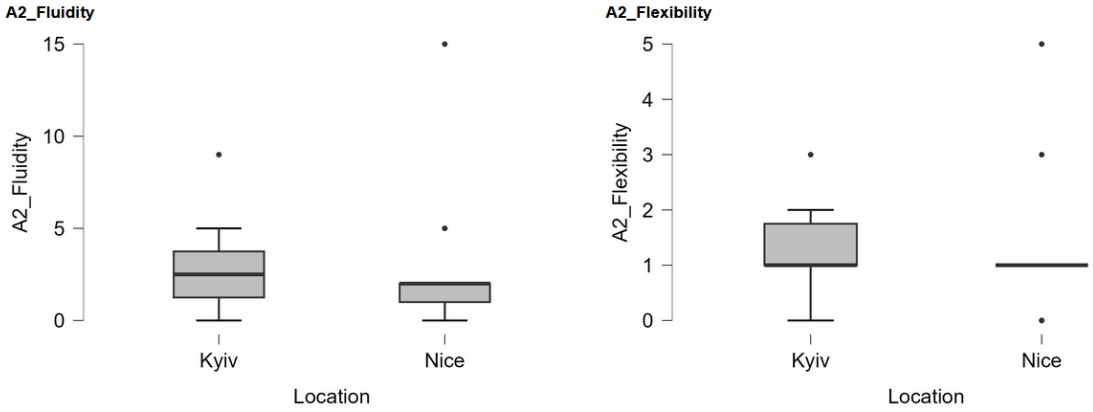

Figure 6: Fluency and Flexibility in *A2* among Kyiv and Nice participants

Despite a similar average, we could observe that the distribution of the DT scores of fluency and flexibility in *A2* are more diverse among Kyiv participants than those in Nice. There was no significant difference in fluidity scores between the Kyiv and Nice groups in *A2*, t(27) = 0.218, p = 0.829, neither in flexibility, t(27) = 0.036, p = 0.972.

6. Discussion

The analysis of the Nice and Kyiv participants shows some differences, especially in relation to originality in *A1*. The second activity (*A2*) shows a lower level on each of the DT components, which is a normal observation due to the prior experience acquired when solving the first instance of the task, which required fewer configurations (fluidity), different configurations (flexibility) and events that did not require engaging in original configurations (originality) compared to the first instance (A1), in which the participants were required to engage in higher trial-and-error explorations of the configurations and generate a higher number of ideas (DT). Observing a lower number of original solutions compared to fluidity and flexibility is part of the expected operationalisation of Guilford's DT components, in which originality is evaluated according to the rarity of the solutions within the same age category (Strutynska & Romero, 2023).

The elevated average value of the originality component (*A1*) among Kyiv participants compared to those in Nice is attributed to the daily challenges faced by learner-players in Kyiv amid wartime stress. This includes coping with issues such as power outages, lack of heating, occasional water shortages, cooking difficulties in the

absence of electricity, closed shops, malfunctioning household appliances, inoperable ATMs, the necessity to interrupt studies and work, and navigating the city amidst air raids. The chronic stress induced by wartime conditions contributes to the heightened readiness of Kyiv participants to tackle various problems, potentially explaining their superior performance in generating original ideas during the *A1* instance of the *CreaCube* task. The variability of the results among Kyiv participants could be understood in the different ways this chronic stress affects the different participants.

Therefore, their readiness to solve problems in the novelty situation of *A1* is higher among the Kyiv participants than that of the participants from the Nice group. In addition, in such difficult war conditions, the opportunity to attend a playful activity with modular robotics *CreaCube* also brought positive emotions to participants from the Kyiv group. It distracted them from the current situation in the country. This allowed them to relax, which can also serve as an additional factor in a higher level of CPS (Strutynska & Romero, 2023).

Despite a limited sample size, this study is an opportunity to consider playful interventions to help Ukrainians engage in creative activities and value the DT capacities developed under stressful war situations. The experimenters and participants in France and Ukraine reported a highly positive, playful experience that, beyond the DT components, is a positive intervention to support Ukrainians through game-based learning activities.

The higher levels of flexibility and originality observed among Kyiv participants in the first instance of the *CreaCube* task (*A1*) suggest a positive impact of the war-induced stressful conditions on their creative thinking abilities. The statistical analysis further supports the significance of these differences, particularly in the originality component.

In the second instance of the *CreaCube* task (*A2*), despite a similar average, the distribution of DT scores for fluency and flexibility is more diverse among Kyiv participants compared to those in Nice. While there is no significant difference in fluency and flexibility scores between the two groups in *A2*, the variation in the distribution indicates a nuanced response to the task among Kyiv participants, possibly reflecting a deeper exploration of creative solutions.

This study highlights the potential of game-based learning interventions, specifically the *CreaCube* task, to support the development of CPS skills, particularly in challenging contexts like wartime chronic stress. The positive experiences reported by participants and experimenters emphasise the broader impact of such interventions beyond measurable DT indicators. The findings underscore the importance of considering playful approaches as valuable tools for supporting individuals in creative activities and cognitive development, especially in the face of adverse conditions.

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AI Statement :We also declare that we did not use AI tools to develop this paper.

Ethics Statement: All procedures performed in studies involving human participants were in accordance with the ethical committee of Université Côte d'Azur (*Comité d'Ethique pour les Recherches Non Interventionnelles*, CERNI, 20196). Informed consent was obtained from all individual participants included in the study.

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