Cognitive room for Design education: Theoretical aspects

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Abstract:

The normal aspect of rooms dedicated to Design education tend to use exhibitions of actual and past student's work as a strategy to inspire creativity in their students. By other hand, the maintenance of the same objects in that room can lead to some boringness as students or worker look to the same things for a period. This leads us to the problem we wish to reflect: Can a room be designed to be user-adaptative allowing multi-sensory experience in line to the educational process in a Design setting? Our goal was to describe the possible link between the educational process and the contribution of a room that is cognitive adaptable to the different needs of that educational process. To achieve this, a theoretical study was conducted to propose a framework for cognitive rooms creation, based on augmented cognition concepts. The concepts of creativity, visual pollution and human-environment interaction understood as cognitive workload were confronted in order to create a technology-based concept of a room that is adaptative to cognitive needs of it users, in a design creational process setting. Theoretically it seems possible to create a room that adapts to one's educational needs, including emotional status, one aspect that can directly be associated with the creativity performance in Design. The implementation of a simulated room based on these ideas will help to quantify the real benefit of this theoretical assumptions to Design education and practice. If true it can be traduced to other room-based realities as school rooms.

Keywords:

Adaptative rooms; augmented cognition; education; media as multi-sensory experiences.

Sala cognitiva para a educação em Design: aspetos teóricos

Resumo: Normalmente, as salas dedicadas à educação em Design tendem a apresentar exposições dos trabalhos atuais e antigos realizados pelos estudantes como uma estratégia para inspirar a criatividade aos mesmos. Por outro lado, a manutenção dos mesmos objetos expostos pode levar a sensações de tédio, à medida que os estudantes ou trabalhadores observam as mesmas coisas por um dado período. Estes dados levaram-nos a refletir sobre: Pode uma sala ser projetada para ser adaptativa ao usuário, permitindo a experiência multisensorial alinhada ao processo educacional em um ambiente educacional de Design? O nosso objetivos era o de descrever o possível vínculo entre o processo educativo e a contribuição de uma sala cognitiva adaptável às diferentes necessidades desse processo educacional. De modo a alcançar o que nos propusemos, elaboramos um estudo teórico com o objetivo de propor uma estrutura para a criação de salas cognitivas, baseada em conceitos de cognição aumentada. Os conceitos de criatividade, poluição visual e interação homem-ambiente, entendidos como fadiga cognitiva foram confrontados para projetar um conceito baseado em tecnologia de uma sala que é adaptativa às necessidades cognitivas de seus usuários, em um ambiente de processo de criação em Design. Teoricamente, parece possível criar uma sala que se adapte às necessidades educacionais, incluindo o estado emocional, um aspeto que pode ser diretamente associado ao desempenho da criatividade no Design. A implementação de uma sala simulada com base nessas ideias ajudará a quantificar o benefício real dessas suposições teóricas para projetar a educação e a prática. Se for verdade, pode ser traduzida para outras realidades baseadas em salas como salas de aula.

Palavras-chave: sala adaptativa; cognição aumentada; Educação; media como experiências multissensoriais.

Sala cognitiva para la enseñanza del Design: aspectos teóricos

Resumen: Normalmente las salas dedicadas a la educación de diseño tienden a utilizar exposiciones del trabajo actual y pasado de los alumnos como una estrategia para inspirar creatividad en los mismos. Por otro lado, el mantenimiento de los mismos objetos en esa sala puede llevar a algo de aburrimiento cuando los estudiantes o trabajadores buscan las mismas cosas por un período. Eso nos ha levado a querer explorar lo problema: ¿se puede diseñar una sala para que sea adaptada por el usuario y permita una experiencia multisensorial en línea con el proceso educativo en un entorno de Design? Nuestro objetivo era lo de describir el posible vínculo entre el proceso educativo y la contribución de una sala que sea cognitiva adaptable a las diferentes necesidades de ese proceso educativo. Para eso, se realizó un estudio teórico para proponer un marco para la creación de salas cognitivas, basado en perspectivas de cognición aumentada. Los conceptos de creatividad, contaminación visual e interacción entre humanos y medio ambiente entendidos como carga de trabajo cognitiva se confrontaron para diseñar un concepto basado en la tecnología de una sala que se adapta a las necesidades cognitivas de sus usuarios, en un proceso creativo de Design. En teoría, parece posible crear una sala que se adapte a las necesidades educativas, incluido el estado emocional, un aspecto que se puede asociar directamente con el rendimiento de la creatividad en el Design. La implementación de una sala simulada basada en estas ideas ayudará a cuantificar el beneficio real de estos supuestos teóricos para diseñar la educación y la práctica. Si es cierto, puede traducirse a otras realidades basadas en salones como salones escolares.

Palabras clave: salas adaptativas; cognición aumentada; educación; los medios como experiencias multisensoriales.

Salle cognitive pour l'enseignement du Design: aspects théoriques

Résumé : En règle générale, les salles consacrées à l'enseignement du Design ont tendance à présenter des expositions de travaux actuels et passés réalisés par les étudiants comme une stratégie pour inspirer leur créativité. D'autre part, l'entretien des mêmes objets dans cette pièce peut être ennuyeux pour les étudiants ou les travailleurs qui recherchent les mêmes choses pendant un certain temps. Ces données nous ont amenés à réfléchir sur: est-ce qu'une salle peut être conçue pour s'adapter à l'utilisateur, permettant une expérience multisensorielle en ligne avec le processus éducatif dans un contexte de Design? Notre objectif était de décrire le lien possible entre le processus éducatif et la contribution d'une pièce cognitive adaptable aux différents besoins de ce processus éducatif. Afin de réaliser ce que nous avons défini, nous avons développé une étude théorique a été menée pour proposer un cadre pour la création de salles cognitives, basée sur des concepts de cognition augmentés. Les concepts de créativité, pollution visuelle et interaction homme-environnement, considérés comme une charge de travail cognitive, ont été confrontés afin de concevoir un concept technologique d'une pièce adaptative aux besoins cognitifs de ses utilisateurs, dans un cadre de processus de création. Théoriquement, il semble possible de créer une salle qui s'adapte aux besoins éducatifs, y compris le statut émotionnel, un aspect qui peut être directement associé à la performance créatrice en Design. La mise en place d'une salle simulée basée sur ces idées aidera à quantifier le bénéfice réel de ces hypothèses théoriques pour concevoir l'éducation et la pratique. Si cela est vrai, il peut être transformé en salles de classe par d'autres réalités basées sur les salles.

Mots-clés: espaces adaptatifs; cognition augmentée; éducation; les médias comme expériences multi-sensorielles.

Introduction

One of the main concepts related to the Design process is the creative leap (Dorst, 1996), described by some authors as the moment where the designer passes from a '*making sense of the future'* to '*giving shape to the future'*, i.e. building a solution (Sanders, 2017).His importance is reflected in the literature as the pedagogical tools to achieve it are frequently discussed along the years. It includes the feeling that we need to increment cognitive studies that first, understand the learning process in Design teaching and second, try to propose different approaches to improve it. One of the strategies used in this process is to create a specific environment where the student develops this process. Thus, it seems that the environment assumes an essential role for the academic attainment of the student competencies, as it can facilitate or prejudice the Design process itself. Considering that this process is trained to be used as a professional tool, so the professional environment assumes similar importance.

The increasing amount of information one needs to visualize, integrate, and interact in our days can lead the human being to a situation of cognitive workload. Cognitive workload is considered to be the decrement of cognitive processing one can demonstrate when exposed to a self-regulated activity for a long period of time (McMorris, Barwood, Hale, Dicks, & Corbett, 2018). Other perspective of cognitive workload includes the idea that neural resources are limited. It distribution along the tasks one need to achieve during normal work, and the amount of attention one need to put on it, can lead to an unbalance between the mental workload and the attentional reserve concept (Miller, Rietschel, McDonald, & Hatfield, 2011). By other words, if such task is mentally demanding, it can need more attention and thus, more mental resources, and so it leads to the use of the attentional reserve. The same occurs if the person is exposed to different sources of information that share between them the person's mental resources as this situation can limit cognitive processing and consequent performance decrement (Jaquess et al., 2017; Miller et al., 2011). In the case of the Design process, this situation could lead to the failure of the creative leap and the ability to produce a solution. So, the effectiveness of a task is related to a normal cognitive function that does not use all the cognitive resources, i.e. maintain some attentional reserve (Jaquess et al., 2017). The Design process includes the collection of information from different sources, that serves as inspirations for Design solutions orientated to a need. This process usually is simulated in an educational environment to train students in real-life settings and, most of the times, the different information is placed in the room as an exhibition, contributing to the inspiring process, (see for example Sanders, 2017), but also at the work environment. We can see the positive contribution of this approach to information management easily, but some awareness needs to be taken into account as this information can also limit the cognitive function of students or workers (Jaquess et al., 2017; McMorris et al., 2018; Miller et al., 2011), and affect the solution production or output.

To build some project that considers these assumptions, that can lead to an experimental setup to confirm any relation or cause-effect phenomena, basic research needs to be conducted as is theory-oriented. As defined by Lens (Lens, 1987), in basic research, theory-oriented predictions are based on theoretical conceptualizations that help researchers create empirical studies for its confirmation. Without a theoretical exploration of the concepts we wish to put into confrontation, the meaning of any empiric research is vague as knowledge needs basic research for its development (Lens, 1987).

Thus, the objective of the present study was to perform a theory-oriented research that explores the link between the educational process – in the case related to Design education - and the idea to create a room that is cognitively adaptable to the different needs of that educational process. If this relation is theoretically possible, then it can be orientated to empirical studies that verify its assumptions and to consider this approach as a solution for different educational settings.

We will start with the description of the methodology used, the problem to be considered, the concepts associated, and the framework was a solution could be developed. Then we define some main conclusions and some consideration of this framework application to other areas of interest.

1. Methodology

Basic research, theory-oriented research or general logic and theoretical perspective are methods of analysis that deals with the confrontation of the existent knowledge of one or more different areas, without the need that its exploration serves a practical application. It promotes a reflection and discussion that justify some predictions, but also encourages the creation of assumptions that weren't expected previously (Lens, 1987; Long, 2014). On the other hand, it helps researchers to get acquainted with existent knowledge and to consider different views, perspectives and feelings that could lead to new insights of that knowledge and thus, promote general lines to seek for it confirmation (Lens, 1987). In line with these considerations, we will start this work with the description of the main concepts that we intend to cross and then to describe a framework on which a cognitive room could be materialized. The scenario used to reflect on this framework was the Design Department of the Universidade Lusófona de Humanidades e Tecnologias (DELLI, Lisbon, Portugal), more precisely its undergraduate program of bachelor's in Design.

1.1 – The problem scenario

DELLI is an area built for Design education, that follows the innovative educational orientations for its area (Figure 1). The process of collecting information, the building of an idea and the process towards a solution passes thought several stages were the

student get the tools and competences to become a designer. One of the strategies is to exhibit the work done in the walls to serve different purposes, one of them is to serve as an inspiration to the other project's students are developing in the same or other academic years. That means that every student in the area had access to visual information through these exhibitions in a very interactive environment, were different academic years share the same area.

In one of the curricular units of the Design bachelor's degree at DELLI, we asked second-year students to reflect on problems they find during their academic experience. One of the difficulties student's felt was related to the continuous exposure to the information in the walls, placards and other exhibition supports. In their opinion, the way information was delivered could lead to a feeling of boringness and lack of creativity during the pursuit of another project's development. They then proceed to the deconstruction of the problem and to understand how the information presented in the room could influence the creative process. The result of this reflection, which included some informal interviews to the students that use the DELLI area, pointed out that this feeling was associated both with the quantity of information that was exhibit and by the amount of time the same information was available to be seen. These results were considered the starting point to the idea that a room could be sensitive to different cognitive needs and, to different amounts and types of information. This room flexibility could then promote a better performance during the achievement of the student's projects, contributing the so expected creative leap.

Figure 1 - DELLI area.

1.2 – A possible framework

Some questions need to be reflected before start building a framework were a cognitive room can be materialized as a solution for the exposed problem. First, we needed to consider the human factor, the creative process as a cognitive demanding task. Second, we need to understand how we can monitor cognitive workload. Third, we need to know how a room can interact with its users to adjust the amount of information to be delivered based on the cognitive workload of its users.

To achieve some answers, we need to understand some of the concepts deeply.

1.2.1 – Creative process as a cognitive demanding task

The ability to be creative, innovative, different, seems to pullulate in our day as a criterion for success. This assumption is more accurate in the environments where creativity is essential, like in Design. The process to be creative starts usually by seeking information that can serve as inspirations. Images, colors, sounds, artworks, materials, textures, everything can help the creative process as any of this can be like a sparkle that ignites the creative leap that can turn this information's into a solution (Dorst, 1996). This process produces an environment that facilitates the conception of a solution. This activity starts with the deconstruction of the concepts associated with the propose problem designer needs to configure a solution. It passes through different strategies that orientates designer towards a different perspective of the problem and the reality it is associated with, lead him to combine and explore different views to finally to give the solution a format and a final output. The ultimate solution needs to reflect actual and future needs, by other words, to collect information that comprises past solutions of the problem and that reflects on the future, which is considered as inspiration (Sanders, 2017; Thoring, Desmet, & Badke-Schaub, 2018).

During this creative process, the designer is exposed to an enormous amount of information, that needs to be processed, assessed, and considered. This necessity constitutes a mentally demanding task. Being a demanding mental task, the ability to cognitively process this information needs to reflect a balance between the mental workload and the attentional reserve. If the last is reduced, it can compromise the success of the cognitive process itself (Miller et al., 2011). This premise is even more true if we consider that the Design process implies different tasks from manual to technological techniques to produce the intermediate works, sketches, drafts and the final solution. In contrast, the cognitive fatigue is developed by the amount of cognitive tasks one can execute during a period of time which also alter the physical performance of the designer (McMorris et al., 2018).

Humans can perform tasks that don't use all the cognitive resources (Jaquess et al., 2017), or by other words, we need to assure that some of the attentional reserve is present to allow the correct development of any cognitive task. Translating it to the

Design process, the creational activity needs to focus on an amount of information that is profitable for the creative process. Other forms of data, not needed for that task, should be avoided or decreased, to limit the use of the attentional reserve preventing the decrement of how effective the creative task is fulfilled.

This cognitive workload and associated decrement of physical performance is in the base of the occupational phenomenon of burnout, a condition that affects the working ability of a person. It's importance give it a place on the calendar of the World Health Organization (WHO) for the creation of a mental health policy for the workplace (WHO, 2005, 2013). Burnout and other mental related conditions can occur as chronic stress or even depression, related to the maintenance of cognitive workload (Cinaz, Arnrich, La Marca, & Tröster, 2013). Depression is present in more than 264 million people around the world (GBD 2017 Disease and Injury Incidence and Prevalence Collaborators, 2018).

1.2.2 – Strategies to monitor cognitive workload

Several strategies are presented in the literature to assess cognitive workload. One of the easiest ways to collect data on it is to use self-reporting tools as the NASA Task Load Index, visual analog scale (VAS), Burnel mood scale (BRUMS), current mood state scale (CMSS), profiles of mood states (POMS). Other is to access the amount of perceptive mental workload (Cinaz et al., 2013; Jaquess et al., 2017; McMorris et al., 2018). Another way is to use physiological variables like event-related potential (ERP), measure by electroencephalography (EEG), and heart rate variability (Baik et al., 2019; Cinaz et al., 2013; McMorris et al., 2018; Mehler, Reimer, & Wang, 2017; Yeh et al., 2016).

The first ones have the problem to be more subjective, as it depends from the decision of the subject, which can be socially and culturally influenced (see for example Atalaia, Abrantes, & Castro-Caldas, 2015), and what can lead to some decisions that do not reflect entirely the subjects need.

The second and third, allows a more objective measure, which decreases social and cultural influence and even the subjects own will. If the data collection is performed in a way that subjects do not need to be submitted to a very demanding laboratorial apparatus and procedure, it could serve as an easy-to-use measure to control information and environment in a cognitive room.

1.2.3 – Strategies to allow human-room interaction based on cognitive workload levels or information needs

We can take some examples from other areas of research that are dealing with similar problems, as augmented cognition and augmented reality.

Augmented cognition is an area that seeks to develop environments were humans can react to information with a better result. This conception is based on the use of

several sensors that monitors the subjects along a task. They provide more or less information to the subject as he demonstrated an increment of his performance in the task trained (Agarwal & Dagli, 2013). In the area of augmented reality, the main idea is to put information inside typical life environments, and to make it useful and orientated to different needs. The success of this interaction is dependent of the use of wearables and to solve problems that include sensors accuracy, environment factors, human-computer interaction and human cognition (see for example, Tsai & Huang, 2018).

One of the concepts we can traduce from these areas is the use of sensors to monitor subjects' signs that can help in the control of the information or type of room that is needed. The other concept is that the room could integrate an adaptative management. By other words, to incorporate the user behavior during a task that can lead the room to better adjust to the user needs based on his behavioral history (Tsai & Huang, 2018).

The information that can be selected can fall into two general categories. The first is related to the creative process itself, and reflects the information needed to proceed with the creational event. The second is composed of more simple forms. For instance, images, sounds and colors that influence subject's mood, and that can help manage cognitive workload. It's common knowledge that sound, color and images can be used to control subject's mood (Liszio, Graf, & Masuch, 2018; López-Tarruella, Llinares Millán, Serra Lluch, Iñarra Abad, & Wijk, 2018; Whiteford, Schloss, Helwig, & Palmer, 2018). Moreover, it can help in stress management and other mental related disorders. For example, the creation of multisensory rooms to support children with autism and other mental disorders is a reality, for instance since 1975 with the Snoezelen concept (Novakovic, Milovancevic, Dejanovic, & Aleksic, 2019). This concept uses images, colors, sounds, light and other sensorial attributes to create a relaxation environment where the amount of information to be processed is controlled to attain a state of relaxation of the children (Novakovic et al., 2019).

The use of nature images seems to be a good option as it has proven his benefits in attentional restoration and emotional stress situations even in immersive virtual reality settings (see for example, Liszio et al., 2018). Colors seems to be strongly related with the subjects feelings of coziness, safety, elegance, spaciousness, simplicity and luminosity (López-Tarruella et al., 2018). The same is associated with the sound, moreover if it is related with color, as it matches seems to favor emotional associations that can serve different subjects responses (see for example, Whiteford et al., 2018).

1.3 – A framework

Based on the information gathered previously, we start building a concept where a cognitive room could be a solution for the described problem. The solution should comprehend some essential aspects.

First, we started by reflecting on the routine use of an academic or professional room. Normally, a room is a place used both for academic lectures and practical issues related to the development of student's competencies. But also, is the place were students can develop their work, train real life processes and, in the case of Design, the creative leap. So, it needs to be flexible to allow theoretical and practical classes, but also to be a room that favors inspiration for the student to proceed with their work. These considerations can be translated easily to the professional settings which, in the case of Design, follows the same needs with some exception regarding theoretical classes, that could be more related with team meetings or some projects presentations.

Secondly, we reflect that a cognitive room need to manage between different kinds of information that is necessary to serve for the inspiration and the creational process of the designer. It also needs to comprise the option to diminish the amount of information and to deliver a sensitive environment composed by images, colors and sounds that helps that creational process.

Finally, we understood that this idea should incorporate the concept of cognitive workload, and to allow automatic adjustment of the room information to the cognitive workload of its users. As above mentioned, to be possible, it needs to monitor some individual information references that are related to the cognitive workload, which means to create a way to track individual and group information. This data could serve to adjust the room environment.

The study of López-Tarruela et al. (López-Tarruella et al., 2018) used a room orientated to seek for color-related affective impression in a lactation room scenario. To achieve this goal, all the room changed his color to give it user the experience to be studied. A similar solution was proposed for our idea that all the room (walls, ceiling, and floor) could be used to pass information.

With the study of Whiteford et al. (Whiteford et al., 2018), we saw that sound and color interact to create emotional environments. So, the emotional associations between colors and sounds should be present in this situation as it seems to facilitate human-room interaction.

The use of images, more specific nature images, was a good solution to promote relaxation as it shows the study of Liszio et al. (Liszio et al., 2018), so it association with color and sounds should be integrated in the solution proposed.

The Snoezelen concept that associates all of this has proven to be a therapeutic solution for mental related stress situations, as its demonstrated in the paper of Novakovic et al. (Novakovic et al., 2019), meaning that this solution could serve to control cognitive workload and to promote the attentional reserve maintenance and restoration during the different activities, as it seems beneficial (Jaquess et al., 2017; Miller et al., 2011)

To control heart rate, the idea should integrate the creation of a multi-user tool for vital signals assessment, that can be used to adjust the room to individual or group needs, as this signal seems to be one of the easiest ways to achieve this control.

These reflections allow us to build a framework to be used in the concept phase of a cognitive room. The general framework is presented in Figure 2.

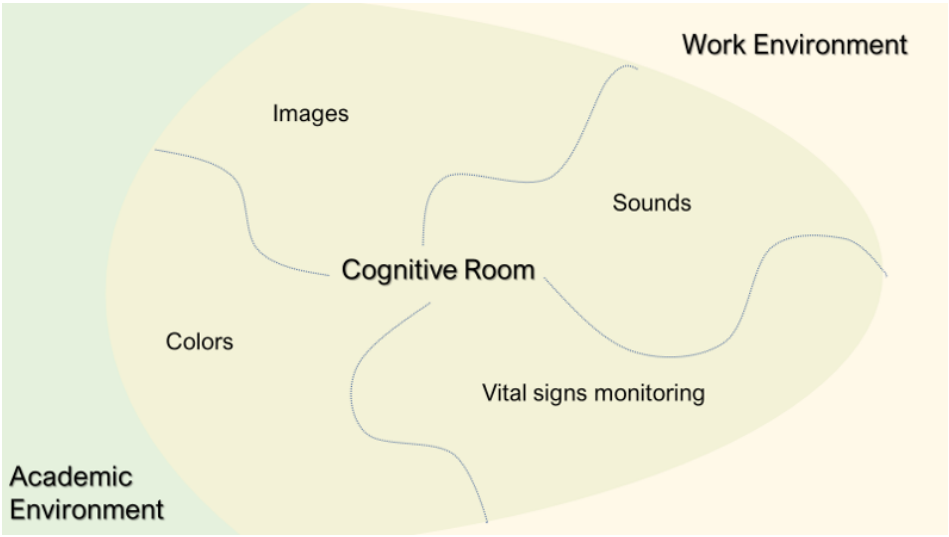

Figure 2 – Cognitive Room Framework

1.4 – First demo

To be able in the future to verify the applicability and the accuracy of our assumptions, we start by building a demo for the concept of a cognitive room adapted to the DELLI area and standard educational settings. This demo serves to create a tool that can allow us to start empirical studies regarding the effects of a cognitive room in the creational leap and cognitive workload of students using DELLI area.

In our first idea for a demo, we consider using only the DELLI walls as the information output. We propose to use big size led screens placed, as indicated in Figure 3. These screens were located at eye level that serves both standing and sitting positions. The information was stored on a cloud-based web service, and a web application was built to allow manual selection of the kind of color, sound, images, themes that the users intend to use in at that time.

Figure 3 – Proposed screen placement at DELLI area.

Another more straightforward idea was to use a projector that could influence only a wall, which limits the concept of a surrounding environment. Still, it could serve as a starting point to access some attributes as the automatic adjustment based on heart rate frequency. A draft is presented in Figure 4. In this we can have a general view of the web-based information manager created by the students, that users can use for both scenarios – classes and as inspirations.

All these ideas, in the first application, need the users to select the intended information they felt adequate to their needs. This option will help to understand different options of information isolation or integration that could facilitate the process that is being studied. It seems logical to start with simple information like colors and sounds, and the classes information selected by the teacher. By monitoring heart rate in all users along a period of time, will give us information about the relation between the room and its users. This information can then be used to build an algorithm that could lead us to a way automatic adjustment could be possible, using a wearable that measures heart rate and interact with the room management system.

Figure 4 – One Wall solution with ceiling laser projector and movement sensors. The web-based solution is projected at the wall.

Final considerations

It seems that it is possible to create a cognitive room that can help students and professionals to pursue their work by promoting a room that is flexible regarding the type and amount of information displayed. It also seems possible that this room can adjust the quantity and type of information depending on cognitive workload of its users. Literature reveals several solutions that can be adapted to this project. Future steps include the simulation of a cognitive room, in a very embryonic stage, at DELLI area during one academic year. This premise can give us insights if this option represents benefits for its users and if so, it can lead to more complete solutions and associated technological improvements to build a more complex cognitive room. If this is possible, to integrate cognitive workload monitoring and adjustable environments for group usage, this idea can be used in future projects involving the professional environments and even school, as it can contribute to classroom improvements.

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