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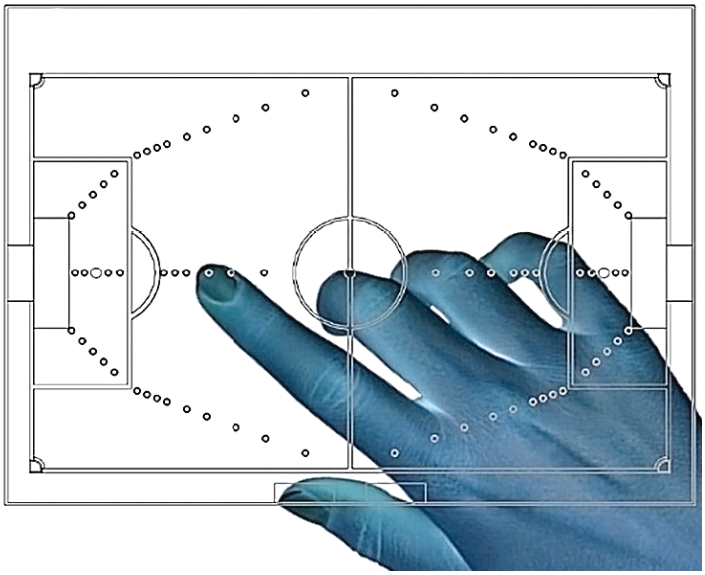

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Contents

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Adaptation of smart-object dimensions in the product design process to reduce household food waste

ABSTRACT

Food waste is a huge problem across the world, but it's especially bad in developed countries such as Malaysia, according to the previous study. It is estimated that 1.3 billion tonnes of food are lost or wasted every year, accounting for one-third of all food produced for human consumption. Hence, the goal of this study is to supplement the solution within the framework of product design process based on the evaluation of food waste behaviour among household in Malaysia. As an approach for acquiring empirical data, a survey study was conducted with 52 respondents in Malaysia, including an analysis of similar existing products on the market, which was then followed by the design process. The findings suggest a multitude of design needs in preventing food waste behaviour among household in Malaysia, including the issues of the existing similar products on the market. Therefore, a few design criteria have been proposed and a set of semi-working food tracking models was successfully developed as a proposal for potential future development and production. It is hoped that the outcome of the study exhibits the synchronization of the product design process inside the smart-object dimensions in order to generate the design that helps to manage and reduce the amount of food waste created among household in Malaysia.

KEY WORDS
Design Thinking, sustainability, food waste, Internet of Things, Smart-Object dimensions

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Introduction

According to Gustavsson et al. (2011), when food is abandoned in the last stage of the food supply chain (FSC), which is at the retail and consumption levels, it is referred to as “food waste”. Meanwhile, Bekteş, (2010) defines food waste as the purposeful or inadvertent disposal of any organic substances that are considered as "food" in terms of culture or biology.

It is estimated that 1.3 billion tonnes of food are lost or wasted each year, accounting for one-third of all food produced for human use (Gustavsson et al., 2011). Garrone, Melacini & Perego (2014) stress that food waste and losses at the retail and consumer level in the United States average 188 kg per capita per year, or $165.6 billion in total. Meanwhile, in Malaysia, Jereme et al. (2016) indicates that households created the largest food waste in Malaysia, with the majority of unconsumed food waste consisting of expired bread, eggs, and rotten fruits, which excluded leftover food. Malaysia is well-known for its diverse and distinctive culinary culture; nonetheless, food in Malaysia is

being abandoned at an alarming rate at the consumer level. On a daily basis, roughly 16,688 tonnes of food are thrown away, enough to feed 12 million people. As Malaysia's population was predicted to reach 33.4 million

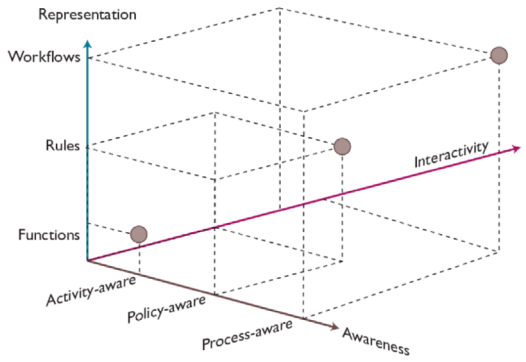
by 2020 and 37.4 million by 2030, this issue is projected to worsen in the next years, owing to economic development, population increase, and urbanization. According to Gunders (2012), food waste in the home is caused by a variety of factors, including lack of knowledge, label date confusion, spoiling, impulsive and bulk purchases, poor planning, and over-preparation, all of which are mostly related to consumer behaviour. Those leftovers are created either because some people are unaware of how to consume leftovers or because they are unaware of how to preserve food for later use in the first place. Gunders also indicates that by shopping carefully, recognizing when food goes bad, purchasing product that is fully edible even though it is less visually appealing, preparing only the quantity of food they need, and eating leftovers can help customers waste less food. Thus, it is critical to modify customers' food waste habits in order to reduce food waste.

Table 1

Food waste generated in Malaysia, adopted from Jereme et al. (2016)

Estimated food waste generated in Malaysia	Generation rate		
Source of food	**(Tonnes/day)**	**(Tonnes/year)**	**Percent**
Household	8,745	3,192,404	38.32
Wet and night markets	5,592	2,040,929	24.50
Food court / restaurants	5,319	1,941,608	23.35
Hotels	1,568	572,284	6.87
Food and beverages industries	854	311,564	3.41
Shopping malls	298	106,288	1.30
Hypermarkets	291	106,288	1.28
Institutions	55	26,962	0.32
Schools	45	21,808	0.30
Fast food / chain shops	2521	808	0.26
Total	**22,793**	**8,331,589**	**100**

This is a product design research paper that examines the problem of food waste among household in Malaysia. Product design is a discipline that has grown as a vital role in producing an innovative product via research and development. One of the current ways to improving human and value quality is to incorporate the human factor into product design by studying human behaviour, obstacles, and needs (Kamil & Abidin, 2013; Kamil & Abidin, 2015; Kamil, Abidin & Hassan, 2018; Sani et al., 2019; Kamil, Abidin & Hassan, 2019a; Kamil, Abidin & Hassan, 2019b; Chumiran, Abidin & Kamil, 2020; Kamil, Shi & Sani, 2020; Sani et al., 2020; Kamil & Sani, 2021). Through the creation of the food tracker design, the major goal of this research is to emphasise the possible growth of theoretical research that is complementary to design practises in order to develop future product design innovation that is coherent to user demands. The food tracker design was built using the frameworks of smart object as propagated by Kortuem et al. (2010). According to Kortuem et al. (2010), the smart object framework was inspired in part by the success of radio-frequency identification (RFID) technology, which is now extensively used for monitoring things, people, and animals. RFID system design is distinguished by a significant contrast between basic RFID tags and a vast infrastructure of networked RFID readers. The notion of the Internet of Things (IOTs) was inspired by the concept of smart objects produced, which articulated within the system architecture, design and development, and human interaction. In terms of core design and architectural concepts, there are three canonical smart object types: (1) activity-aware objects, (2) policy-aware objects, and (3) process-aware objects. Interactivity with function, rules, and processes was formed by these types. In order to build the food tracker design in this study, these frameworks were employed as a template for improving the system's operations. The explanation of the product design process in this study, seeks to extend the breadth of knowledge, leading to further design research inquiry with sustainability relevance.



» **Figure 1:** *Smart-object dimensions illustrate the three canonical object types, activity-aware, policy-aware, and process-aware, adopted from Kortuem et al. (2010).*

The study of the availability and efficacy of current ICT-based solutions and smart technologies for consumer food management and waste reduction

Vogels et al. (2018) investigates and assesses the availability and efficacy of current ICT-based solutions and

smart technologies for consumer food management and waste reduction. It was part of the REFRESH EU research initiative, which seeks to help Europe achieve its objective of decreasing food waste. The study has been conducted based on the strategies as follow: (1) social recipes, which refers to a community- based system of food sharing (Lim et al., 2014; Lim et al., 2017; Yalvaç et al., 2014); (2) eco-feedback, which refers to comparing one's own food waste behaviour to others (Lim et al., 2017); (3) apps and wearables, where different apps and a wearable camera were tested by consumers (Farr-Wharton, Foth & Choi, 2013; Farr-Wharton, Choi & Foth, 2014a; Ng et al., 2015; Hoem, 2017); (4) interactive or smart fridge, which aimed to help consumers organizing the food in their fridge (Rouillard, 2012; Farr-Wharton, Choi & Foth, 2014b; Nguyen et al., 2015); and (5) indirect and direct persuasion, where two variants of a recipe website were investigated in relation to consumer's environmental attitudes and their recipe choice (Aleahmad et al., 2008). Table 2 illustrate the list of apps divided in different categories based on the main functionality that have been included in the study.

According to the study, many of the applications accessible in app stores were created by individuals, have little functionality, and are not updated regularly, but commercial apps created by businesses are generally better maintained, have more feature, and have more installations. Limited functionality, sporadic updates, inadequate information from unknown sources, and inferior usability appear to be the most significant shortcomings of the currently existing apps (especially in apps with combined functionalities). According to Vogels et al. (2018), users appear to be open and interested in applications that assist reduce food waste, according to the study. Many users, however, stated that they could

Table 2

The list of apps divided in different categories based on the main functionality that have been included in the study by Vogels et al. (2018)

Categories	App's Name	Developer	Platform
Reminder apps	BEEP- Expiry Date Barcode Scanner	GPworks	Android
	Date Limite+	Loïc SENCE	Apple IOS
	Expired & Grocery Monitor	Y&A China	Android
	Expiry Date App	EWK GmbH	Android
	Expiry Reminder	CBWorkshop	Android
	Expiration Alarm	MND Apps	Android
	Food Expiration Track	TouchSi Co., Ltd.	Android
	Food Expiration Date	OcApps	Android
	Food 'n Stuff	Sirius Cybernetics Corporation	Android
	FoodLocker	Christian Ghelardoni	Apple IOS
	Food Saver	Salvatore Vivolo	Apple IOS
	Food Storage Helper	Ybgallery	Android
	Food Storage Assistant Pro	DzignStudio	Android
Food sharing apps	OLIO- Food Sharing Revolution	OLIO	Apple IOS, Android
	Ratatouille	Georgia Marenda	Apple IOS
	Afgeprijsd	Gemoro b.v.	Apple IOS, Android
	Too Good To Go	Too Good To Go	Apple IOS, Android
	RedMaden	Martin Bay ApS	Apple IOS, Android
	Rekub	IntoApps	Apple IOS, Android
	Food Share	Mindnotix Software Solutions	Android
	Waste No Food	wastenofood.org	Apple IOS, Android
Planning apps	Bring! Shopping List	Bring! Labs AG	Apple IOS, Android
	Groceree (FJ)	FJ	Android
	Shopping List Voice Input	TK Solution	Android
	Shopping List	Kiwi3	Android
Integrated apps	CogZum	Ivo Dimitrov	Apple IOS
	Eat This Much- Meal Planner	Eat This Much, Inc.	Apple IOS, Android
	Food Planner	MiniMobile	Apple IOS, Android
	Fridgely	Jump Space Apps	Apple IOS
	Frigo App	Stephane Nguyen	Apple IOS
	Frigo Magic	FrigoMagic.com	Apple IOS, Android
	Home-Time	Jay Juillet	Apple IOS, Android
	Love Your Leftovers	Holroyd City Council	Apple IOS
	Slim Koken	Voedingscentrum	Apple IOS, Android

not see an obvious need for such an app since they believed they did not waste much food. Some of the apps were found to be lacking in incentives to reward and reinforce positive behaviour, had poor user-friendliness, and took a long time to use. Despite the fact that certain apps demonstrated tiny, positive increases in awareness and motivation, none of the apps had an influence on self-reported food waste behaviour (meal planning and groceries shopping). Overall, users felt they had to put in considerably more effort (in terms of time, energy, and endurance) than they got out of the programme (convenience, insights and engagement).

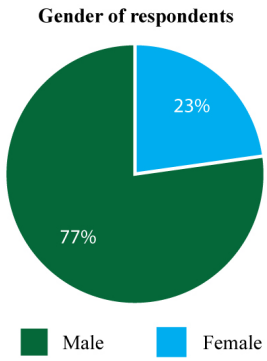
Throughout the study, Vogels et al. (2018) found that user-friendliness is an important factor, implying that the software takes little time to use and requires low cognitive effort to operate. Users will cease using an app if it is not user-friendly. Consequently, using a user-unfriendly software will not result in a change in food waste behaviour. Since users have a minimal intrinsic need to utilise food waste-related apps, Vogels et al. (2018) recommends that the apps should be exceedingly simple to use, with straightforward navigation, a simple app structure, and a limited number of alerts. Users wanted no advertising or banners, but this will be tough with a free app. Manually entering products takes too long and should be automated, such as by scanning food products. To create functionality that makes product input easier and offers correct information about projected remaining shelf life of the items, a well-maintained and up-to-date database of food products is required. However, creating such a database is difficult because most databases are only adequate for one nation and are incomplete. According to Vogels et al. (2018), incorporating a direct insight or highlighting the economic and/or ecological repercussions of user's food-waste related behaviours in an app might serve as an incentive for changing food waste behaviour. Users may establish objectives and observe the impact of their behaviour by incorporating immediate feedback or incentives in applications. Users can also compare themselves to other users. This might boost motivation and increase the likelihood of long-term use of such an app.

Materials, Method and Result

A solid foundation for the design development process set by Godfray (2014), Green, Draper & Dowler (2003), Hoem (2017), Kantor et al. (1997), and McDonald et al. (2006) who investigated the factors associated with food waste behaviour such as: (1) lack of knowledge and understanding of dates labels; (2) unaware of available foods at home; and (3) excessive buying in bulk. Their research, that is also in accord with various research regarding the existing solution to reduce food waste, such as: (1) the decomposition process of organic materials; (2) donating food surplus to people who needed before the food become inedible or spoilt; and (3) minimizing food from getting disposed by reducing the amount of food surplus generation (El–Haggar, Hamoda & Elbieh, 1998; El Haggar, 2010; Poppendieck, 1994; Quested et al., 2011; Skinner, 2017). This information is crucial in the development of food tracker design. In this study, the food tracker design was developed to reduce the amount of food waste created in the household in Malaysia. Therefore, an online survey study was conducted with 52 respondents in Malaysia. The context of the survey study was specifically designed to obtain and clarify the evaluation of food waste behaviour among home consumers in Malaysia, including the optimal design function to be applied in the food tracker design. Respondents were given 20 minutes to complete the survey study.

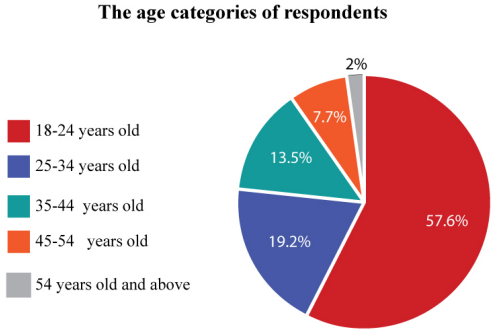
Phase 1: Assessing the Design Needs

The analysis of survey study was part of the design development process to inform design needs and enforce a defined design direction. During Phase 1, the survey results was analysed using Statistical Package for the Social Sciences (SPSS) to get a knowledge of the respondents' food waste behaviour and the appropriate design function required. The results of the survey study are illustrated in figures and table.



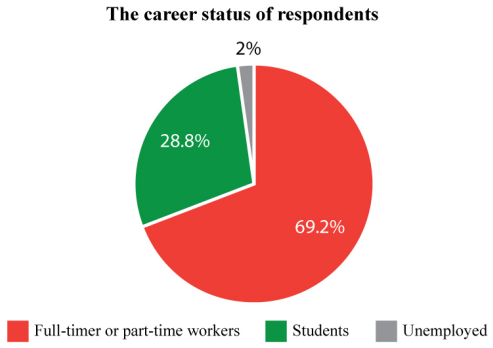
» **Figure 2:** *Gender of respondents*

Figure 2 depicts the gender of respondents who took part in the survey. Based on the data, the majority 77% of respondents are women in comparison to men (23%).



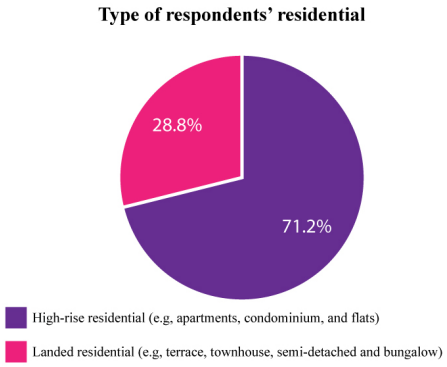
» **Figure 3:** *The age categories of respondents*

Meanwhile, Figure 3 illustrate the age categories of respondents who took part in the survey study which indicates that most of the respondents who took part in the survey study were made up from the age range of 18-24 years old (57.6%), while only 19.2% of the respondents come from the age range of 25-34 years old. Moreover, 13.5% and 7.7% of the respondents respectively from the age range of 35-44 and 45-54 years old, whereas only 2% of the respondents are from the age range of 54 years old and above.



» **Figure 4:** *The career status of respondents*

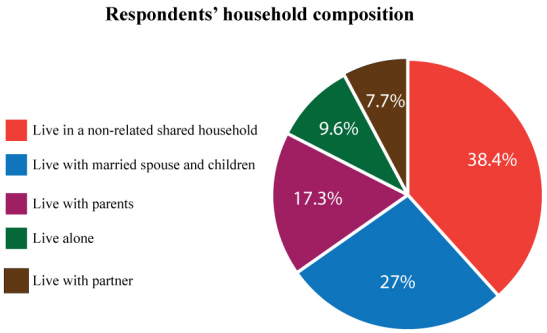
On the other hand, Figure 4 illustrates the career status of respondents which indicates that the majority 69.2% of respondents are full-timer or part-time workers while 28.8% of the respondents are students. Only 2% of the respondents are unemployed.



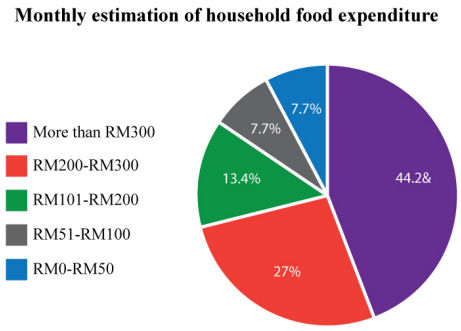
» **Figure 5:** *Type of respondents' residential*

Figure 5 show the type of respondents' residential. Based on the result, the majority 71.2% of respondents are living in high-rise residential such as apartments, condominium, and flats in comparison to landed residential (28.8%) such as terrace, townhouse, semi-detached and bungalow.

Furthermore, Figure 6 illustrate the respondents' household composition. Based on the data, the majority 38.4% of the respondents are staying in a non-related shared household followed by 27% of respondents who are staying with their married spouse and children. Meanwhile, only 17.3% of the respondents are living with their parents, followed by 9.6% of the respondents who are living alone, whereas 7.7% of the respondents are living with their partner.



» **Figure 6:** *Respondents' household composition*

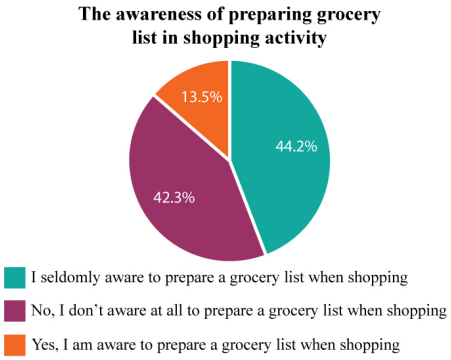


» **Figure 7:** *Monthly estimation of household food expenditure*

Figure 7 depicts the result of a survey in which respondents were asked about the monthly estimation of household food expenditure. Based on the data, the majority 44.2% of the respondents spend more than RM300 for food monthly. In addition to this number, 27% of respondents spend approximately RM200-RM300 for food monthly, followed by 13.4% of the respondents who spend around RM101-RM200 monthly.

Meanwhile, only 7.7% of the respondents who monthly spend around RM51-RM100 and RM0-RM50 respectively. As a result, it is reasonable to conclude that while monthly estimates of family food expenditure vary, the majority of households would spend more than RM300 on food each month.

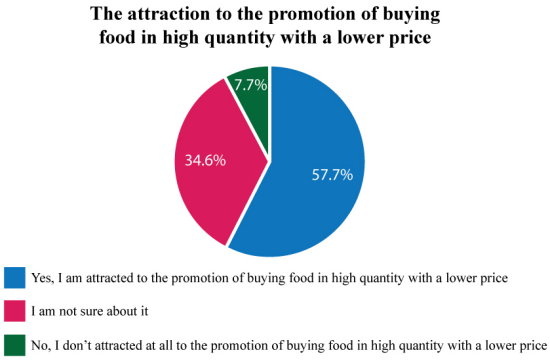
Figure 8 depicts the result of a survey in which respondents were asked about the awareness of preparing grocery list in shopping activity. Through the result, only 13.5% of the respondents are aware to prepare a grocery list when shopping while the majority 44.2% of respondents are seldomly aware to do so. However, 42.3% of the respondents did not aware at all to prepare a grocery list when shopping.



» **Figure 8:** *The awareness of preparing grocery list in shopping activity*

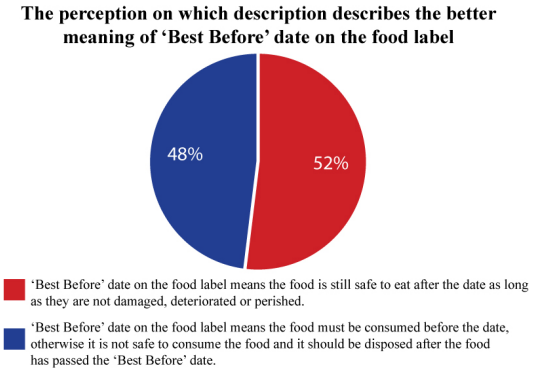
Hence, it is possible to infer that household awareness of the need of making a food list when going shopping is still low. This might lead to impulsive grocery shopping and food waste.

Figure 9 depicts the result of a survey in which respondents were asked about their attraction to the promotion of buying food in high quantity with a lower price. Based on the result, the majority 57.7% of respondents are attracted to the promotion of buying food in high quantity with a lower price while 34.6% of respondents are unsure about it. Meanwhile, merely 7.7% of respondents were uninterested in such promotions. Therefore, it is reasonable to conclude that the promotion of purchasing large quantities of food at a cheaper price has a significant influence on household purchasing decisions, resulting in needless grocery purchases and food waste.



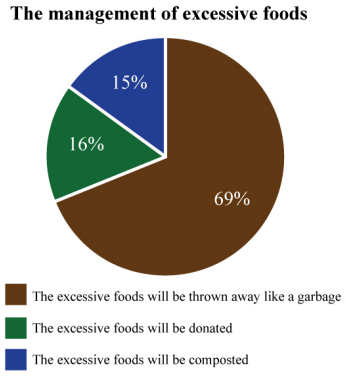
» **Figure 9:** *The attraction to the promotion of buying food in high quantity with a lower price*

Figure 10 illustrates the result of a survey in which respondents were asked about their perception on which description describes the better meaning of 'Best Before' date on the food label. Through the study, the majority 52% of the respondents perceived that 'Best Before' date on the food label means the food is still safe to consume after the date as long as they are not damaged, deteriorated or perished. Meanwhile, 48% of respondents perceived that 'Best Before' date on the food label means the food must be consumed before the date, otherwise it is not safe to consume the food and it should be disposed after the food has passed the 'Best Before' date. Based on the results, it is reasonable to conclude that more than half of the respondents in this survey were unaware of or misunderstood the date labelled, which according to Green, Draper & Dowler (2003) is connected to household food waste behaviour.



» **Figure 10:** *The perception on which description that best describes the meaning of 'Best Before' date on the food label*

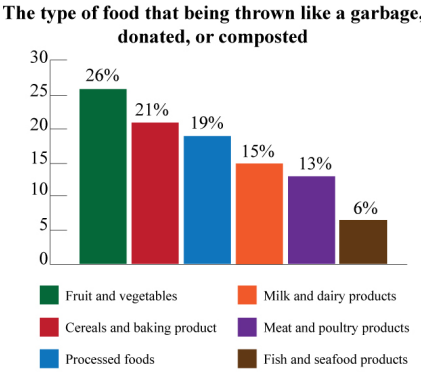
Figure 11 illustrate the result of a survey in which respondents were asked on how they manage the excessive food. The study revealed that, the majority 69% of the respondent indicates that they eventually throw away the excessive food like a garbage. Meanwhile, 16% of the respondents donated the excessive food, whereas only 15% of the respondents composted excessive food. Based on the data, it is plausible to conclude that more than half of the participants in this study are practicing a food waste behaviour.



» **Figure 11:** *The management of excessive foods*

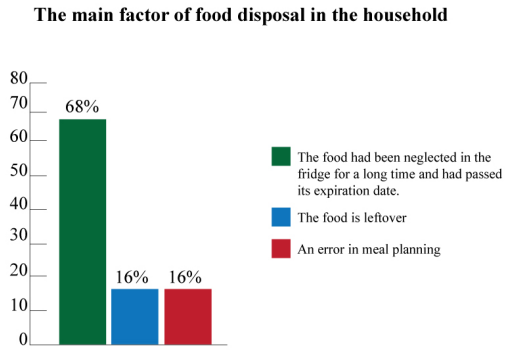
Figure 12 shows the results of a survey in which respondents were asked what type of food they threw away, donated, or composted. According to the data, fruit and vegetables are the most common type (26%) of excessive food thrown out, donated, or composted, followed by cereals and baking product (21%), processed foods (19%), milk and dairy products (15%), meat and poultry prod-

ucts (13%), and finally fish and seafood products (6%). Based on the data, it can be inferred that the percentage of food that is thrown away, donated, or composted varies depending on the type of food; nevertheless, fruit and vegetables have the greatest percentage.



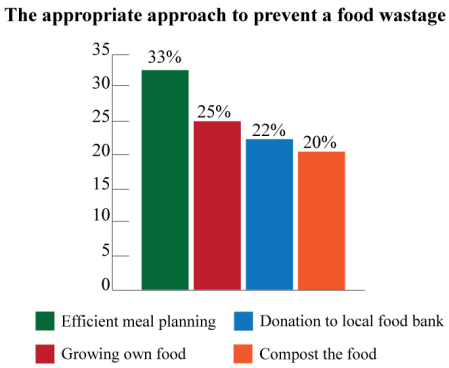
» **Figure 12:** *The type of food that being thrown like a garbage, donated, or composted*

Figure 13 depict the result of a survey in which respondents were asked about the main factor of food disposal in their household. The result indicates that the majority 68% of the respondents disposed the food because it had been neglected in the fridge for a long time and had passed its expiration date. Meanwhile, both leftovers and error in meal planning share the same percentage of 16% as a factor for the food being disposed. Based on the data, it is reasonable to conclude that food that has deteriorated, been damaged, or perished as a result of being forgotten in the fridge for a lengthy period of time and having passed its expiration date is becoming the major factor in household food disposal.



» **Figure 13:** *The main factor of food disposal in the household*

Figure 14 depict the result of a survey in which respondents were asked about the appropriate approach to prevent a food wastage. The data illustrate that the majority 33% of the respondents perceive that an efficient meal planning would be the appropriate approach to prevent a food wastage, followed by growing own food (25%), and donation to local food bank (22%). However, only 20% of the respondents indicates that composting would be the best choice.



» **Figure 14:** *The appropriate approach to prevent a food wastage*

Throughout the analysis of the survey, the information of condition and situation of food waste among household was provided based on the assessment of respondents' perception, behaviour, and background, including a multiple design needs and opportunities for the household. The understanding of the design needs through the survey study help to determine the optimal design function and design knowledge that may be improved further in the food tracker design process. As a result, five elements of solutions were developed based on the summary of the survey study (see Table 3).

Table 3

The description five elements of solutions

Elements of solutions	Descriptions pre-processing classification
Management of supply procurement	The food tracker should be able to manage purchased supplies and update the remaining food quantities in the household regularly to prevent possessed food from deteriorating, being damaged, or perishing, resulting in its disposal.
Utility, Conveniences, and Efficiencies.	The food tracker design should be able to provide users with the elements of utility, conveniences, and efficiency to boost the interactivity between the potential users and designed product.
Perception and Awareness	The food tracker design should be able to perceive potential users with the awareness of their possessed foods.
Activity Tracking	The food tracker design should be able to provide potential users with tracking features to manage and plan their possessed foods.
Personalisation and Appeal to Emotion	The food tracker design should be aesthetically appealing and easier to personalize.

Phase 2: Generating Design Ideations

Previously in Phase 1, the five elements of solutions were generated through the result of survey analysis. Meanwhile in Phase 2, the five elements of solutions help in brainstorming process to generate the design criteria of the food tracker design (see Table 4).

Table 4

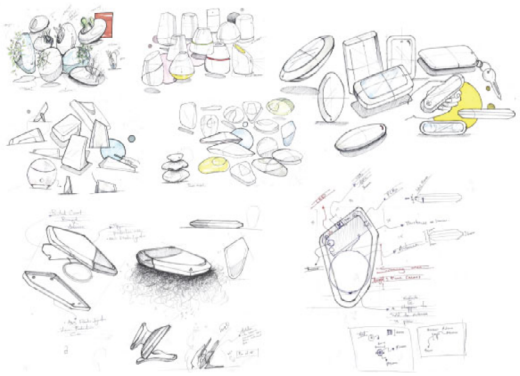
The description design criteria

Design Criteria	Descriptions pre-processing classification
Simplicity and minimalist	Aim to provide potential users with the simplicity of tracking food with minimal effort through advancement of technology.
	Minimalist interface.
	Implementing the concept of Internet of things (IOTs) in the designed product.
User friendly	Aim to provide potential users with the elements of utility, conveniences, and efficiency.
	User-friendly interface to boost the interactivity of the potential users.
	Connecting to various hardware using RFID technology for better tracking.
Interactive	Aim to provide potential user with the awareness of their possessed foods.
	Interactive and simplistic interface, reminder, planner, and notes.
Emotional design	Aim to help elevating potential users' positive thoughts through element of aesthetic.
Aesthetic	Aims to make the design form and interface more appealing and help to boost interactivity of the potential users.
	The colour of design form and interface inspired by nature to interactively react to the potential user's visual thought.
	Elegant design.
	Minimalist interface.
Quality material and Apps	Using quality, nimbler, and safer material and apps such as three-dimensional (3D) printed plastic Polylactic acid (PLA) and Adobe XD.

The food tracker design will be integrated with minimalist and simplicity criteria through the application of IOTs concept and minimal interface, based on the stated design criteria. Through technological advancements, it is envisaged that potential users would be able to track their possessed food with minimum effort. Furthermore, it is anticipated that the integration of a minimalist interface with RFID technology would provide potential users with usefulness, convenience, and efficiency. The aforementioned criteria will determine whether or not the designed product is user-friendly. An interactive and intuitive interface, as well as a reminder, planner, and notes, will be incorporated to offer potential users with knowledge of their possessed foods. Furthermore, nature-inspired colour and shape will be used in the design with the goal of raising potential users' good sentiments through aesthetic elements and making the design form and interface more appealing. The colour of the design form and interface inspired by nature is intended to connect with the potential user's visual mind and make the design seem elegant. Finally, we have also suggested that a quality, nimbler, and safer material and apps such as three-dimensional (3D) printed plastic Polylactic acid (PLA) and Adobe XD to be used for design production.

The mood board design concept (Figure 15) was first executed in Phase 2. The mood board was produced as a visual guideline based on the design objectives. Natural forms and shapes, colours, and physical qualities were all employed to create the visual guideline that was used in this study. These visual guidelines help the research team choose the best design direction based on the responses from the survey study. For example, the aesthetic characteristics of food tracker design were influenced by the forms, shapes, and colours of pebble stones. The textural features of the design will be impacted by the physical attributes of natural components buried in pebble stones, such as the soft texture.

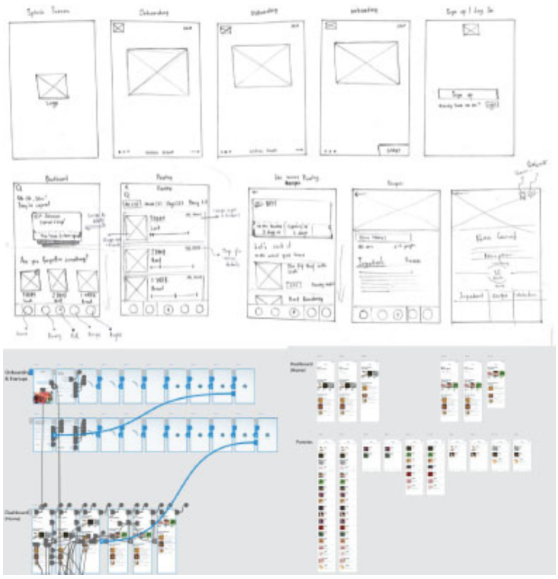
» **Figure 15:** *Design concept mood board*



» **Figure 16:** *Design ideations development*

A sketching activity (Figure 16) based on the mood board design concept was used to start the design ide-

ation process. Throughout the process, components created from design criteria and visual guidelines in the mood board design idea were used to shape the food tracker design's visual shape. Nevertheless, Lo-fi product interface development in sketches was generated before it being transformed into Hi-fi interface using software Adobe XD (see Figure 17).



» **Figure 17:** *Product interface development from Lo-fi interface in sketches to Hi-fi interface using software Adobe XD*

The result of the sketching activity was turned into a three-dimensional (3D) design using Autodesk Inventor 3D Design software at the conclusion of Phase 2 (see Figure 18). The design's dimension and visual look were realistically increased during the process. The 3D design result aids in gaining a thorough knowledge of the food tracker design, including textures, colours, and product dimensions.

» **Figure 18:** *3D design visualization*

Phase 3: Model making process

During Phase 3, the model making process was executed. Making a model helps the research team to see how the product tangible looks, and to ensure that a product is viable. This involved three-dimensional printing process using 'Ultimaker 2+' 3D printer (based on 3D files generated in Phase 2). During the process, the Polylactic acid (PLA) filament spool was loaded into the 'Ultimaker 2+' 3D printer and then fed straight into the extrusion headset to the printer's nozzle. The 0.4mm nozzle of the printer is warmed to the required temperature (around 200-210 °C), and the motor then allows it to melt and pushes the filament through the nozzle. The extrusion nozzle follows the specified coordinates, allowing the blackened material to harden and refresh on the plate. This cross-section printing cycle is continued until the item is entirely produced, layer by layer. Following that, the development of the app interface, the installation of the printed circuit board, and the product furnishing was executed (see Figure 19). Throughout the process, the technical aspects of the model were investigated on a regular basis to ensure that all design flaws were addressed. At the end of this stage, a preliminary grasp of the restrictions inherent to the food tracker design, as well as how real users would behave, think, and feel when handling the end product, was gained.

» **Figure 19:** *3D printing process, printed circuit board installation, and apps interface development*

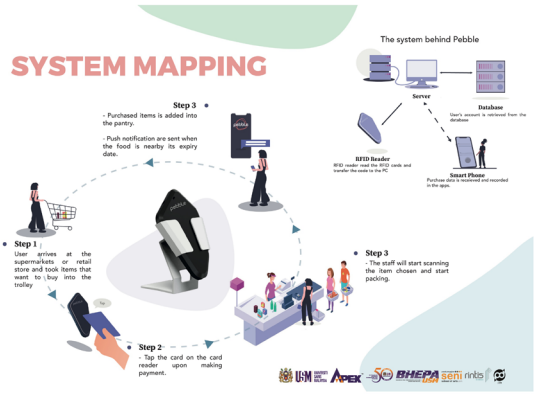
After the serial iteration phases, which include many modifications to fit the correct comfort of the user, the final semi-working model is completed (Figure 20).

» **Figure 20:** *The final semi-working model*

The aesthetic qualities incorporating the current food tracker design style or fashion, as well as the technological consideration highlighting how real users would behave, think, and feel when handling the finished product, are the key features confirming the non-working model.

Discussion

Based on the study, our research team proposes Pebble, a food tracker device aim to minimise the amount of food waste among household in Malaysia. The feature of Pebble food tracker is based on a loyalty scheme that exists in supermarkets. Pebble's apps were designed to keep track of their purchased goods' expiration dates, regularly update the remaining food quantities in the household, as well as to serve as a meal reminder for user since they frequently forget what they have in the house. Buying the same or more food may add to food waste because the commodities are frequently over their expiry date.



» **Figure 21:** *The system mapping of the Pebble food tracker*

Figure 21 depicts the Pebble's system mapping in terms of how the service works. It begins with the user taking the items desired, then the user proceeds to the checkpoint for payment once all of the goods required have been taken. When the user reaches at the checkpoint, they must place their items on the conveyor belts and scan their Pebble card. The cashier system will retrieve information and data about the user's account in Pebble applications once the card is tapped. The staff began scanning the products and retrieving information from the supermarket's database. Once the payment is completed, the item's details will be saved in the Pebble apps and system. Adapted from the frameworks of smart object propagated by Kortuem et al. (2010), Pebble food tracker was built with RFID tag's reader as a main approach of monitoring the purchased foods. Articulated within the system architecture, design and development, and human interaction through interactive interface and apps, Pebble food tracker enriched the concept of IOTs through three canonical of smart object types:(1) activity-aware objects, (2) policy-aware objects, and (3) process-aware objects. The interactivity of the interface and apps of Pebble food tracker, with function, rules, and processes was formed by these types. Table 5 shows a description of the Pebble's app user interface.

Conclusions

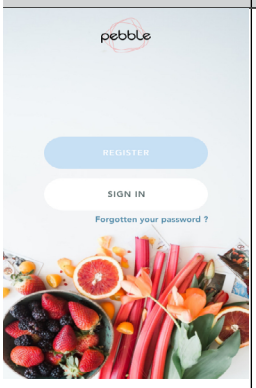
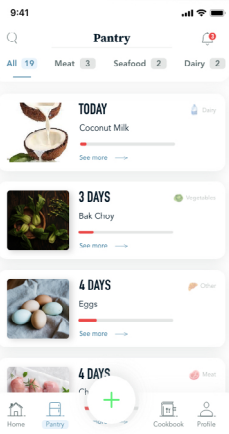
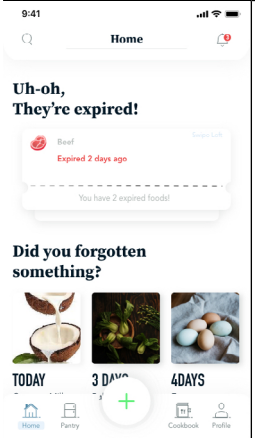
This research has successfully developed food tracking device as its design proposal to reduce the amount of food waste among household in Malaysia. The five aspects of solutions such (1) management of supply procurement; (2) utility, conveniences, and efficiencies; (3) perception and awareness; (4) activity tracking; and (5) personalisation and appeal to emotion are significant to the construction of device, including the apps. The aesthetic design, the integration of interactive interfaces, and the apps criteria in product creation have all contributed to this relevance. Furthermore, because potential users are important stakeholders in design, integrating the empathic protocol into the product design research process emphasises the importance of potential users' feedback. In this situation, the respondents' issue aids in determining the function of the produced design. The five aspects of solutions and design criteria elements have adequately reflected the potential user's need for food waste prevention. The suggested food tracker has the potential to be improved and mass-produced in the future. This may be done by putting the proposed design criteria into practise. The device is expected to help reduce global food waste as a result of this breakthrough. More importantly, the proposed design would allow us to finally reinforce a sustainable development. However, this study has a limitation where a complete user testing and assessment of the product's performance is required in the near future to further evaluate the applicability of the proposed food tracker design. Although there is evidence that apps can raise consumer awareness concerning food-waste related behaviour, such as awareness about which food products are already in stock at home or about product shelf life, more research is needed to determine whether and when these tools are effective in changing consumers' actual food waste. Furthermore, there are additional approaches to influence behaviour that need to be investigated more in connection to food waste behaviour, such as nudging tactics, financial incentives for positive behaviour (compliments, achieving goals, and earning points), and education programmes, among others.

Acknowledgements

Pebble food tracker design copyright number: AR2020004956 is patented under the ownership of Universiti Sains Malaysia.

Table 5

Pebble's app user interface

Interface	Descriptions pre-processing classification	Interface	Descriptions pre-processing classification
	User Registration/Login Pages i. To keep track of the food they have bought, users must first log in to their account. ii. To make it easier for them to control their meals.		Pantry i. Purchased products are listed in a hierarchical order, with the foods that are most likely to deteriorate at the top. ii. The foods are divided into various types to make it easier for users to find what they are looking for. iii. Swipe left on the meal users have consumed, or right on the items they have discarded. iv. The instruction will be statistically recorded.
	Getting a Pebble Card i. Newcomers must fill up their personal information and address in order to receive a Pebble card. ii. The card will be delivered to their address; no card linkage is necessary. iii. Each account is given one Pebble card. However, in a household with a few individuals, multiple cards can be connected to the shared customized account. It gives members of the household more flexibility and efficiency in keeping track of their purchased foods.		Cookbook i. The selected recipe displays a list of components that are readily available in the pantry. ii. Foods that are not in the pantry must be purchased by the user. iii. Select the shopping list icon and enter the necessary quantity. iv. When going grocery shopping, the user may view the list to keep track of what ingredients are required, preventing impulsive purchases and overstocking. v. Recipes and their instructions
	Dashboard i. Expired foods will be presented at the top. ii. Regular update of foods quantities that are about to expire in the household are listed below. iii. Recipe suggestions at the bottom of the page to show users how to use the ingredients in their pantry.		Profile i. The percentage of food consumed or discarded is displayed. ii. The user's purchase history is displayed below to help them keep track of and manage their monthly budget. iii. Grocery List (Left) iv. Barcode scanning — Scanning items purchased without a point-of-sale system (i.e., wet markets) v. Voice search – Other methods of entering food.

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User friendly haptic tool for soccer fans with vision disabilities: Design and proof of concept

ABSTRACT

Loss of eyesight inflicts multiple difficulties in everyday lives' tasks affecting not just the visually impaired but also their loved ones. The sense of being depleted by the otherwise visually perceived satisfaction from attending various events becomes a burden not just in terms of joy but also in relation to accompanying parties. The aim of this research work was to provide a worthy perceived experience of attending a soccer match with the company of a friend, centered at the visually impaired person's needs and perspective. The methodology developed was based on a holistic approach combining a number of creative tools, in order to explore, visualize and evaluate the proposed solutions, with advanced CAD modeling, rendering techniques and 3D printing technology for improved representation and prototyping of the final product. Evaluation via multi-criteria decision-making casted the developed system as quite usable, suitable for assisting the visually impaired users in absorbing valuable information regarding the real time progress of a live soccer event using the selves-developed tactile interface. That way, visually impaired people are able to use the final product with a great deal of success and "feel the view" and the "time" in a variety of cases, allowing them to better enjoy attending an entertainment event, such as soccer, with the interactive company of a friend.

KEY WORDS

Haptic tool, visually impaired people, CAD modeling, conceptual design, criteria based model design, 3D printing, soccer, AHP. Fuzzy SAW

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Introduction

Late advances in precision modeling enable the design and manufacture of physical haptic structures capable of translating and rendering visual representations to non-visual representations (Tobitani et al., 2021; Yao et al., 2020; Milos, Vujčić & Majnarić, 2021). Regarding the latter, in (Mc Gee et al., 2000) the authors identified possible effective combinations of haptic and live auditory textural information that exploit the sense of touch (haptic), the feeling of motion (kinesthetic) and the received force-feedback from the mechanical production of information sensed by the kinesthetic system, and the sense of pressure, temperature and

pain felt by the skin (either cutaneous or tactile when focused upon pressure solely). These combinations indicate that it might be possible to take advantage of the sense of touch as an alternative means to that of sight for sending and receiving information.

Efforts have been made (Mordini et al., 2018; Mulloy et al., 2014; Brewser & Murray-Smith, 2001) to develop sensory substitution devices (SSDs) aiming to convert the stimuli normally accessed by a certain modality into appropriate stimuli suitable for being accessible by another sensory modality. The aim of such SSDs is to improve efficiency, effectiveness and satisfaction of the end user. Yet, resolving in arbitrary combinations of multimodal information of different senses has been proven to be rather ineffective (Gori et al., 2016) receiving low user acceptance rates and demonstrating virtually no adaptability regarding children's use. Some of the downsides of such high technology devices reported in the literature (Elmannai & Elleithy, 2017) include, but are not limited to, invasiveness of the proposed system, excessive cognitive load, absence of an action-perception link and simultaneous integration of multiple types of sensors.

Sensory substitution devices' requirements are likely to differ depending on the application and the specific impairment of the end user. Thus, it was deemed important (Hamam et al., 2008; Hayward & Astley, 1996) to evaluate the quality of experience of sensory substitution haptic devices throughout the various development stages to extract application-specific optimum design principles for tactile interaction (Challis, 2000). Included among others are touchable elements as reference points, organization of commands and functionalities as well as simplicity and usability of common functionalities (Chiti & Leporini, 2012).

The purpose of this research work is to assist the visually impaired in absorbing valuable information regarding the real time progress of a live soccer event using a selves-developed tactile interface by improving the quality of experience. The usability of the developed haptic tools is evaluated by combining Analytic Hierarchy Process and Fuzzy Simple Additive Weighting theory. AHP has been proved ideal for comparing the weights of criteria in several other evaluation experiments (Kabassi, 2021a; Kabassi,2021b) and the comparison of several multi-criteria decision making models (Kabassi, 2021a) such as SAW, WPM, TOPSIS, VIKOR, PROMETHEE II revealed that SAW is very robust and maintain partly the ranking of the alternatives even if the weights of the criteria change.

The criteria used for the evaluation of the usability of the system represent the main requirements for designing such interfaces. These criteria have been acquired by analyzing related papers on the field (Mc Gee et al., 2000; Haman et al., 2008; Gori et al., 2016; Challis et al., 2000) as well as other evaluation experiments (Kabassi et al., 2018; Kabassi & Maravelakis, 2015). High precision 3D modelling (Tobitani et al., 2021; Maravelakis et al., 2012; Maravelakis et al., 2014a; Maravelakis et al., 2014b; Axaridou et al., 2014) and printing (Wang et al., 2017) systems were encompassed for maintaining consistency of mapping in order to ensure the validity of the described actions in both the visual and the non-visual representations. Static tactile representations were selected to be asserted within the interface environment, as dynamic ones would have inflicted the difficulty of having to notify the user in real time where within the interface a change has occurred (Caspo, Wersenyi & Jeon, 2016). Also, height was mainly used rather than depth as the discriminating factor for the user to home-in on certain action tactile features, while the latter, i.e. depth, was selected for indicating and safely discriminating the dense faithful mapping of the football pitch layout within the penalty area on the high precision 3D model.

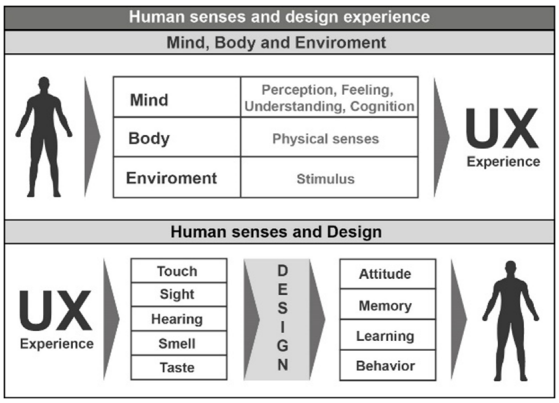
As analyzed thoroughly in the sections to follow, this research approach addresses several key deficiencies identified in the literature (Jia et al., 2013; Hasper et al., 2015), such as ease of use, natural engagement in terms of how close is the interaction to the real world, minimal invasiveness and need occupation of other senses, easy to comprehend, low cognitive load, minimal training requirements, constructive simplicity with faithful points, manageable size and weight, portability and most significantly general satisfaction as indicated by the end users themselves. In order to achieve the best possible level of satisfaction of the impaired user multi-criteria decision-making (MCDM) (Oprocovic & Tzeng, 2004) has been encompassed. Indeed, multi-criteria decision making models have been proved very successful in evaluating using expert knowledge the usability of a system (Adepoju et al., 2020; Bilalis et al., 2006; Konstantaras, 2013; Konstantaras, 2016).

An evaluation experiment depends on several and often conflicting criteria. MCDM techniques provide a flexible and transparent way to find solutions to such complex problems (Yiannis et al., 2020). Indeed, in order to aggregate the different criteria, different MCDM models have been developed. These models are being used before evaluating software for example, websites of cultural (Kabassi, Botonis & Karydis, 2020; Kabassi, Karydis & Botonis, 2020; Kabassi et al., 2019; Kabassi & Maravelakis, 2015) or environmental (Kabassi & Martinis, 2020; Kabassi, Martinis & Papadatou, 2019) content. The main advantage of multicriteria decision making methods in comparison with other methods and theories is that they provide a well-defined methodology for aggregating the values of the different criteria, which may have different weights of importance. Some MCDM models also have a well-defined way of calculating weights of importance for each criterion. This advantage makes MCDM methods preferable either for using solely or

in comparison with other methods, such as fuzzy logic (Hamam et al., 2008; Liu & Wang, 2007; Maravelakis et al., 2006), soft-computing and deep learning (Kuo & Liang, 2012; Konstantaras et al., 2008; Konstantaras et al., 2021; Konstantaras, 2020). Different MCDM methods also provide different ways for combining the criteria. Therefore, an important decision while applying MCDM is selecting the method that best fits the needs of the problem being solved. For example, there are methods (Büyüközkan & Ifi, 2012) that implement pairwise comparisons (eg. VIKOR, TOPSIS), methods that calculate the linear combination of criteria (eg. SAW), etc.

Conceptual Design Methodology

The proposed holistic methodology targets the users' senses in order to offer a worthy perceived experience and is being successfully applied in other product design industries as well (Manavis et al., 2020; Manavis et al., 2021). It starts with an approach that contains many aspects of the users' experience focused from their perception and understanding point of view to their physical senses and environmental stimulus. The designer is forced to deal with an increasing number of issues when more and more senses are deployed in order to offer a worthy user-targeted experience. The senses are the basis for stimulating the user's attitude, memory, learning and behavior. As a result, users receive greater satisfaction from the product's usage (Figure 1). It is evident that a great deal of attention is given towards the social aspect of the user-centered approach, which traditionally does not get a great deal of attention from researchers and designers (Efkolidis et al., 2019).

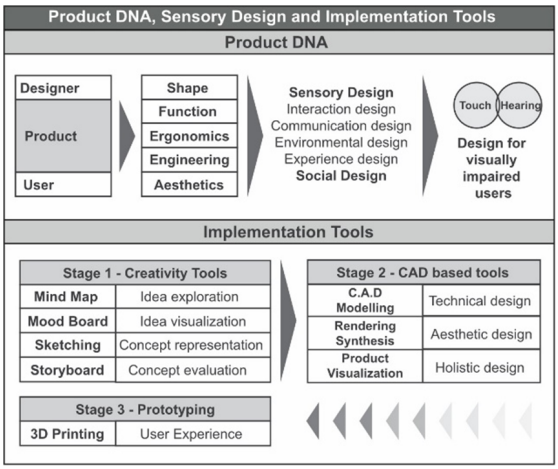


» **Figure 1:** *Designing the experience via human senses*

Figure 2 depicts a roadmap that leads both the designers and users in implementing an experience that can satisfy all segments of the product market. From both the designers' and the users' point of view, the product is generally perceived as the experience that contains a number of characteristics i.e. shape, function, ergonomics, engineering, aesthetics, while these lead to highlight each one of them, when using different design approaches i.e. sensory design, interaction design, social design. When the design is targeted for visually impaired users, the main focus is concentrated on sensory design and social design principles, that use to a greater extend the senses of touch and hearing.

There are three separate stages for which certain tools are used for successfully implementing the proposed methodology:

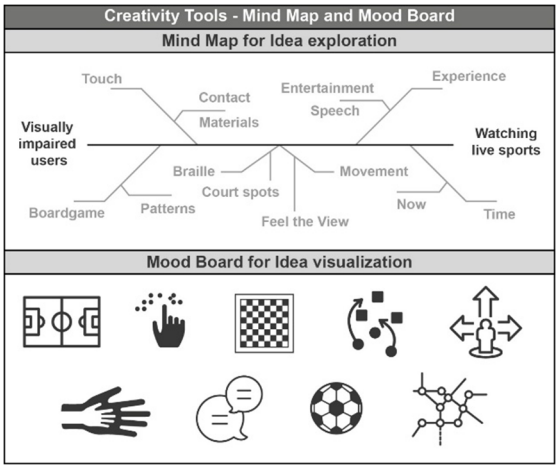
- a number of creativity tools are used to explore, visualize and evaluate the proposed solutions from the entire design space available. This means that more cases can be dealt with for a variety of products and demands.
- CAD models with advanced rendering techniques offer an almost realistic representation of the designed solution and satisfy the holistic targeted approach.
- 3D printing is the basis of prototyping and thus the user can very early in the design process experience its use and offer feedback via his/her opinion. This feedback that comes directly from the user, releases the design creativity towards directions, that offer multiple added value to the user. The prototype of the product is getting attention early in the design cycle and thus minimizes future design mistakes and corrections, affecting drastically the reduction of the development cost.



» **Figure 2:** *Roadmap for implementing the proposed methodology*

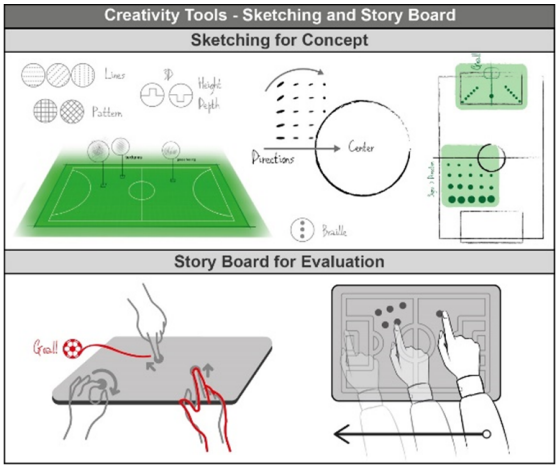
Both mind-map and mood-board tools were used in order to explore the design space and visually gather pieces of information and features, that can be incorporated later on the proposed product (Figure 3). The problem under consideration is the "live football watch experience of visually impaired users". The user needs to touch the product under consideration and listen, if possible, at the same time so as to understand the motion of the players and the position of the ball while the game unfolds.

Visually impaired people are well adapted to communication via the braille language so a similar technique would be easier to grasp and use. The board of the game should be built with patterns, thus leading/guiding the users when they touch the patterns in order to be able to immediately understand the area of the real-life football pitch where the players controlling the ball participate in. The rules of the game should be easily explained and transferred to the user in an intuitive way. The user should be able to experience the term "time" in a variety of options. That means that the sense of the real player being in a specific area in the real football pitch and the direction of the ball to another area should be easily transferred to the visually impaired person, the principle "feel the view" should be implemented via his/her senses. It is evident that a similar approach can be followed for other sports that could also become openly available to visually impaired users.



» **Figure 3:** *Exploring and visualizing design ideas*

The next step followed was the extensive use of sketches (Figure 4). A number of different patterns were incorporated. Basic and easy to touch geometries offered ease of understanding the general football pitch layout. Then smaller patterns are used around the center of the football pitch for offering the experience of stepping away from the center. Smaller or larger line patterns together with their inclination offer the possibility to recognize the position of the player from the center and his direction of motion. The same applies when using the same idea in the area of the goalpost. Then with the use of the gameboard the way of successful implementation is presented. In this case, the presence of the user assistant is revealed and his role is highlighted. The assistant will guide the finger of the visually impaired person at the appropriate position in the gameboard in accordance to the actual position of the player controlling the ball on the football pitch, while at the same time will be able to describe how the game is evolving. It is at this moment that both senses (touch and hearing) unite their inputs for assisting the user to completely understand the evolution of the game in real time.



» **Figure 4:** *Sketching and visually evaluating the design proposal*

Finally, a Computer-Aided Design (CAD) based model was used for addressing all the previous concepts and provide access to a 3D solid model. The 3D solid model was used for acquiring a 3D printed gameboard to be used for testing the users' experience following the holistic design process and approach (Kyratsis, 2020; Kyratsis, Kakoulis & Markopoulos, 2020). The CAD model is actually a gameboard that was used by the visually impaired user, while the assistant was leading the user's finger and described in real time, the evolution of the game (Figure 5). In such a way, the user was able to understand the position and motion of both the active players and the ball at the same time as the game unfolded.

» **Figure 5:** *3D printing-based prototype used during live game*

Criteria-based Model Design

The proposed approach introduces a tailor-made model design of a football pitch encompassing action zones suitably constructed to meet specific criteria (Ardévol, 2013) categorized as design assessment, reality approach and user experience, outlined below:

A) Design Assessment (DA)

- Orientation (DA_0). Does the model have clear touchpoints for the initial orientation?

- Size (DA_1). Do you need to overreach in order to discover the full extent of the haptic model?
- Height as a filtering Mechanism (DA_2). How go the different heights on the model help you recognize and discriminate different areas of the field?
- Level of "empty space" Areas (DA_3). Are there areas on the haptic model that cannot be easily interpreted?
- Faithful touchpoints (DA_4): How natural is the change between touchpoints on the haptic model?
- Perceived Roughness (DA_5). How physical roughness facilitates the interaction with the model?

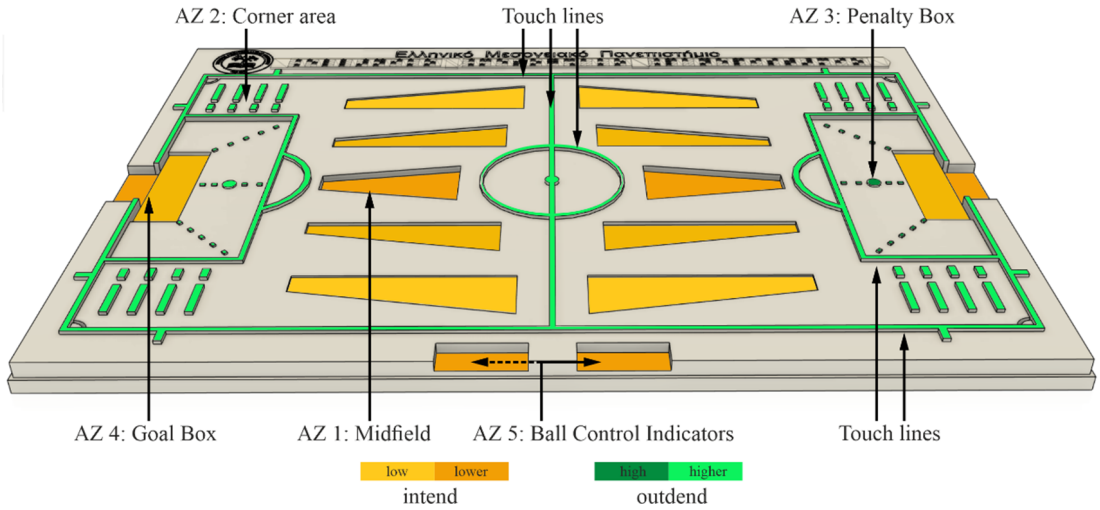
B) Reality Approach (RA)

- Natural engagement (RA_0): How close do you think is the interaction to the real world?
- Multisensory integration (Acoustic & Touch) (RA_1). How well acoustic senses are intergraded into the haptic model?
- Consistency of Mapping (RA_2) Do you think that there is a consistency between different touchpoints on the haptic model?

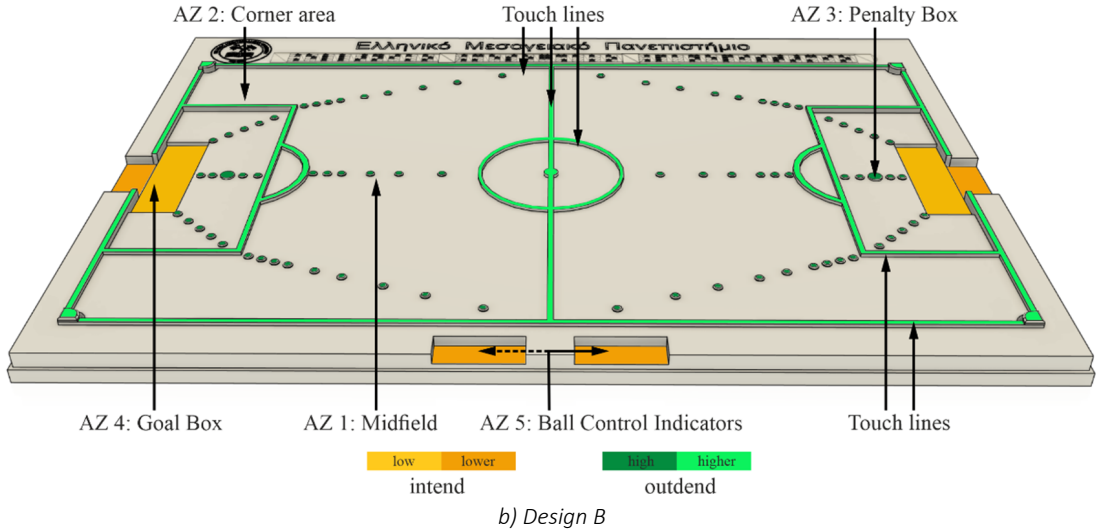
C) User Experience (UX)

- Invasiveness (UX_0). How free do you feel by using the haptic model?
- The natural expression of action (UX_1): does the model allow you to act naturally?
- Cognitive Load (UX_2). How much attention is required for using the haptic model?
- Training Effort Required (UX_3). How much training is required in order to start using the model?
- Level of Satisfaction (UX_4): How satisfied does the user feels from his/her experience with the system?

For the model to satisfy the aforementioned criteria it was deemed necessary to clearly discriminate between field touchlines and action zones.



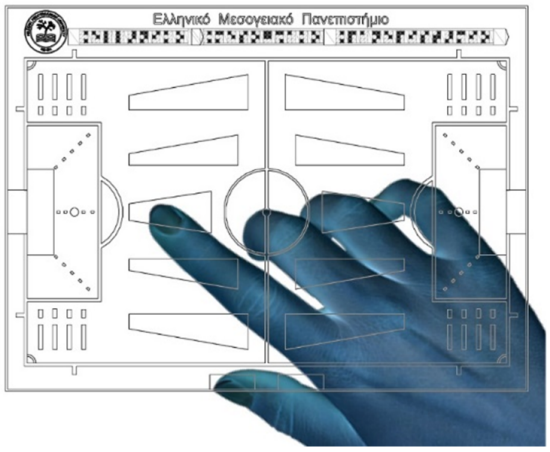
a) Design A



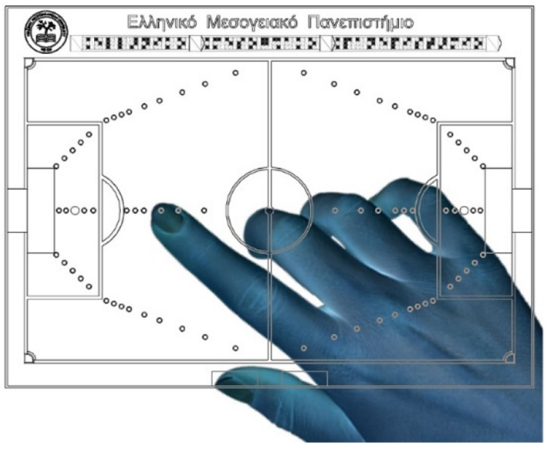
b) Design B

» **Figure 6:** *3D models of the football gameboards*

In terms of the former, all touchlines have been printed outdented as continuous lines for it is easier to detect by touch, follow along and quicker to realize which is which (side touchline, goal line, halfway line, center circle, penalty box, penalty arc, goal box) in terms of positioning. The dimensions of the field can be tailor-maid to the user's hands in such a manner to single-handedly be able to reach from one goal line to the center of the football pitch. This enables to user to receive full haptic input of the gameplay on either side of the field and be clear at any time on which team is pressing forward and who is defending. The shortest distance between the touchlines (Figure 6a Touchlines), i.e. that of the goal box and the goal line is made certain to fit in the full width of the user's pointer finger, and based on that the entire football pitch touchlines are printed to scale in analogy to the actual football pitch. Furthermore, special care has been taken to ensure that there are no empty areas significantly larger than the tip of the pointer-finger in order to enhance the real-time continuous haptic interpretation of the model while game-play unfolds.



a) Design A



b) Design B

» **Figure 7:** *Haptic use of the 3D football gameboard models*

Regarding the latter, initially all action zones (Fig 6a, AZ1-4) were designed intended to easily discriminate from touchlines. This approach proved efficient in wide open-spaced areas among the touchlines such as the action zones (Figure 6a. AZ1) amidst the halfway line and the penalty box and arc areas. The available spacing in these two areas on either half of the football pitch enabled the inward extrusion of five parallel action zones that start wide near the middle of the football pitch and narrow-in while approaching the penalty box. Narrowing occurs from one side of the action zone corresponding to the actual side of play in the football game with the exception of central advancement action zone in line with the central circle and goal area where both sides of the action zone lean inwards. Also, the depth of these action zones reduces while leaning towards the sides of the football pitch.

These cultivations to the model were possible as the available spacing was enough to fit an adult's finger to either of the aforementioned action zones. This is not the case though when the game-play unfolds on either side, left or right, of the penalty boxes (Figure 6a, AZ2). In those areas the available spacing is limited and a better haptic perception was received for pairs of parallel outdented lines, four pairs in each penalty box side, with the innermost action lines set to one third of the length cast to the outward action lines.

Once game-play proceeds into the penalty box touch lines (Figure 6a, AZ3), this is being immediately haptically perceived by a sudden drop in the field depth. Also, to further assist with the ease of haptic awareness of the direction of play within the penalty box, three outdented dotted lines have been printed; between the two in field right angles of the penalty box and the two equivalent points of the goal box as well as a vertical dotted one running through the penalty spot expanding right in the center in between the penalty and goal boxes. The penalty spot itself is printed as an exaggerated circular limp rather than a dot sized mark of the latter action line.

Once in the goal box (Figure 6a, AZ4) a further increase in depth is haptically sensed nicely trapping the user's finger into it, enabling it to comfortably move sidewise and sense the goal line. Outside the goalpost, the goal line is as a wall whose height reduces when moving from the goal box to the penalty and from the penalty box to either near the corner-kick area.

The goal-line within the goalposts is sensed by yet another increase in depth, and with a slight side-twitch of the finger the user can feel just one of the aforementioned picky wall corners corresponding to the two vertical goalposts enabling the user to realize at which side of the net a goal was scored. Missed goal efforts that ended up outside the goalposts are being perceived by guid-

ing the user's finger over the goal-line wall extending outside the left or right goalpost within the goal area.

If a corner kick is awarded the finger is guided to the corner area where the corner mark can be haptically sensed intended. In case of a free-kick, the equivalent touchpoint is either of the two in-filed corners of the goal box. In the event of a goal being scored the finger is directed to the exaggeratedly outdented kick-off spot in the center of the halfway line crossing the center circle.

Just outside the sideline and on either side of the football pitch the benches of the two teams are printed by being intended (Figure 6a, AZ5). The purpose is for a second finger, most suitably the thump, to be used for sensing one of the benches at any time depending on which team has control of the ball at any given instance. Finally, near the corners and outside the sidelines and the goal-lines outdented markers have been placed to indicate proximity to the corner area.

The prototype in Figure 6a was then tested early in the design process by two types of visually impaired users, users that were born blind or lost their eyesight during infancy and users that had lost their eyesight later on in their lives. From the received feedback, the former group stated that they were happy with the compactness of action zones amongst football pitch lines as it felt easier for them to absorb haptic information while they had their finger moving upon the 3D football pitch model by their guide. On the other hand, the latter group of users that had the opportunity to visually sense and remember a football pitch during gaming action stated that they would prefer a greater degree of empty space amongst football pitch lines. The greater degree of freedom apparently lessens the rate and effort in absorbing haptic information while their fingers were guided upon the 3D football pitch model. The possible expected loss of tactile orientation when crossing larger empty spacings appears to have been compensated by the former knowledge of actual football pitch layouts and unfolding football games.

These early design stage observations encouraged the authors to yet another design shown in Figure 6b targeted at people that were not visually impaired throughout their lives. This design includes fewer action zones in terms of numbers but also the dimensions of each action zone have been narrowed down to dotted lines to provide the additional increment in empty spacing as was suggested by the users. To account for proximity to penalty areas, the dotted lines were designed to be denser there and narrower towards the center of the football pitch. Haptic use of both 3D football gameboard models is shown in Figure 7a and Figure 7b, respectively, with both the hand and football gameboard model being plotted to scale with respect to their actual physical dimensions.

Evaluation: Applying Analytic Hierarchy Process for Calculation of the Weights of the Criteria

In order to evaluate the usability of the proposed system an evaluation experiment was performed. In the past, a quite different approach of combining usability evaluation with fuzzy MCDM (Büyüközkan et al., 2012; Chou, Chang & Shen, 2008) theories have been proposed. More specifically, the Fuzzy Simple Additive Weighting theory (FSAW) (Chou et al., 2008) has been combined with the framework for usability evaluation of virtual environments proposed by Sutcliffe & Gault (2004) for performing usability evaluation of Virtual Reality (VR) environments. In this paper, we show how Analytic Hierarchy Process (AHP) (Saaty, 1980) can be combined with FSAW for evaluating the usability of a Haptic Tool for Soccer Fans with Vision Disabilities. AHP is one of the most popular MCDM theories. AHP aims to analyze a qualitative problem through a quantitative method. This method uses the nine-point scale developed by (Saaty, 1980) for the evaluation of the goal with the criterion as well as the criterion with the alternative (Mulubrhan, Akmar Mokhtar & Muhammad, 2014).

Steps of the AHP theory were followed as given by (Zhu & Buchman, 2000): 1) Developing a goal hierarchy, 2) Setting up a pairwise comparison matrix of criteria, 3) Calculating the weights of the criteria. Taking into account these steps, the steps for implementing the theory are:

- **Developing a goal hierarchy**, which involves:
  1. **Forming the overall goal:** The overall goal is to evaluate the Haptic Tool for Soccer Fans with Vision Disabilities
  2. **Forming the set of criteria:** In this step the set of design criteria is being used.

- **Setting up a pairwise comparison matrix of criteria:** In this step a comparison is implemented among the criteria of the same level. For this purpose, the set of three (3) human experts who acted as decision-makers were asked to make the pairwise comparisons of criteria. The group of human experts was formed by two experts in usability and one expert in software for people with vision disabilities. The decision makers agreed on the values presented in the tables below.

One table was completed for the pairwise comparison of the criteria of the first level (Table 1), one for the sub-criteria of Design Assessment (Table 2), one for the sub-criteria of Reality Approach (Table 3), and one for the sub-criteria of User Experience (Table 4).

Table 1

Pairwise comparison of the criteria of the first level

	DA	RA	UX
DA	1	0.50	0.20
RA	2	1	0.33
UX	5	3	1

Table 2

Pairwise comparison of the sub-criteria of Design Assessment

	DA_0	DA_1	DA_2	DA_3	DA_4	DA_5
DA_0	1.00	1.00	0.50	0.33	0.20	2.00
DA_1	1.00	1.00	2.00	1.00	2.00	3.00
DA_2	2.00	0.50	1.00	0.50	0.50	2.00
DA_3	3.00	1.00	2.00	1.00	0.50	1.00
DA_4	5.00	0.50	2.00	2.00	1.00	1.00
DA_5	0.50	0.33	0.50	1.00	1.00	1.00

Table 3

Pairwise comparison of the sub-criteria of Reality Approach

	RA_0	RA_1	RA_2
RA_0	1	1	2
RA_1	1	1	2
RA_2	0.5	0.5	1

Table 4

Pairwise comparison of the sub-criteria of User Experience

	UX_0	UX_1	UX_2	UX_3	UX_4
UX_0	1.00	3.00	1.00	7.00	0.13
UX_1	0.33	1.00	0.33	2.00	0.17
UX_2	1.00	3.00	1.00	5.00	0.50
UX_3	0.14	0.50	0.20	1.00	0.11
UX_4	8.00	6.00	2.00	9.00	1.00

- **Calculating weights of criteria:** After making pairwise comparisons between the criteria of the same level or the sub-criteria of the same criterion, estimations are made that result in the final set of weights of the criteria. For this purpose, the principal eigenvalue and the corresponding normalized right eigenvector of the comparison matrix that is calculated, provide the relative importance of the various criteria being compared. The elements of the normalized eigenvector are now the weights of criteria or sub-criteria. In terms of simplicity, we had used the 'Priority Estimation Tool' (PriEst) (Sirah, et al., 2015), an open-source decision-making software that implements AHP, for making the calculations that the theory requires. This process resulted in the following weights for the criteria and the sub-criteria:

A) Design Assessment (DA)→ w_{DA} = 0.122

- Orientation (DA_0)→ $w_{DA\,0}$ = 0.100
- Size (DA_1) → $w_{DA\,1}$ = 0.238
- Height as a filtering Mechanism (DA_2) → $w_{DA\,2}$ = 0.140
- Level of "empty space" Areas (DA_3) → $w_{DA\,3}$ = 0.189
- Faithful touchpoints (DA_4) → $w_{DA\,4}$ = 0.230
- Perceived Roughness (DA_5) → $w_{DA\,5}$ = 0.104

B) Reality Approach (RA)→ w_{RA} = 0.230

- Natural engagement (RA_0) → $w_{RA\,0}$ = 0.400
- Multisensory integration (Acoustic & Touch) (RA_1) → $w_{RA\,1}$ = 0.400
- Consistency of Mapping (RA_2) → $w_{RA\,2}$ = 0.200

C) User Experience (UX)→ w_{UE} = 0.648

- Invasiveness (UX_0) → $w_{UE\,0}$ = 0.170
- The natural expression of action (UX_1) → $w_{UE\,1}$ = 0.070
- Cognitive Load (UX_2) → $w_{UE\,2}$ = 0.200
- Training Effort Required (UX_3) → $w_{UE\,3}$ = 0.040
- Level of Satisfaction (UX_4) → $w_{UE\,4}$ = 0.170

One can easily observe that the criterion 'User Experience' is much more important than the other two criteria. As far as 'Design Assessment' is concerned the criteria 'Size' and the 'Faithful touchpoints' are considered more important than all the others. Regarding the criterion 'Reality Approach' the two sub-criteria 'Natural engagement' and 'Multisensory integration' are equally important and have higher weight of importance than 'Consistency of Mapping'. The 'Cognitive Load', the 'Invasiveness' and the 'Level of satisfaction' are the most important sub-criteria of the criterion 'User Experience', that is considered the most important of all.

Evaluation: Applying FSAW for the implementation of the main experiment

The main evaluation experiment involves the participation of real users, interacting with the tool and answering the questions that correspond to each criterion.

Since AHP performs pairwise comparisons between the alternatives being evaluated and, in this case, there is only one alternative, and a crisp value for the tool being evaluated should be calculated, we combine AHP with FSAW. Fuzzy SAW has been selected because it is easier for users to provide linguistic terms to criteria rather than arithmetic values.

Fuzzy SAW is applied as soon as the weights of importance of all criteria have been calculated. For this purpose, the following steps are implemented:

1. **Forming the set of the tool's evaluators.** This group may involve real users of the tool and/or design experts in software usability for all. More specifically, thirteen nearly fully impaired users from various football club associations cooperated in this research work. Out of the thirteen overall users, four of them were born blind and the nine users had gradually lost their eyesight at various aging stages in their lives.
2. **Assigning values to the criteria.** In order to make this process easier for the users, especially for those that do not have experience in multi-criteria analysis, the users could use linguistic terms for characterizing the fourteen criteria presented at the beginning of this section. The answers to these questions are linguistic terms and show successful each criterion is fulfilled. The linguistic terms are: Very Poor, Poor, Fair, Good, Very Good. All criteria are assigned fuzzy values. This process resulted in Table 5.
3. **Linguistic terms are transformed into fuzzy numbers.** Each linguistic term is assigned to a fuzzy number, which is a vector $\tilde{a} = (a_1, a_2, a_3)$. The matches are presented in Table 6 (Chen 2000).
4. **Aggregating the values of the different evaluators (decision makers).** Each criterion should have at the end only one fuzzy number. For this purpose, the arithmetic mean is used. The arithmetic mean values of two fuzzy numbers $\tilde{a} = (a_1, a_2, a_3)$ and $\tilde{b} = (b_1, b_2, b_3)$ is calculated as follows:

$$\tilde{c} = \left(\frac{a_1+b_1}{2}, \frac{a_2+b_2}{2}, \frac{a_3+b_3}{2}\right) \quad (1)$$

This process results in a triangular number for each criterion in the following Table 7.

5. **Calculating the weighted normalized fuzzy number.** In order to derive a fuzzy score for the system, the values of the criteria are multiplied with the corresponding weights (Equation 2).
$\tilde{f}_{saw}$ is calculated using (2) as a fuzzy number. In order to evaluate the successfulness of the system one can either find which fuzzy number is closer to the value of $\tilde{f}_{saw}$ or calculate a crisp value. The above estimations revealed that the final value for the evaluation of the system is $\tilde{f}_{saw}$ = (4.98,6.15,6.83). This value is between the fuzzy numbers of 'Fair' and 'Good', which reveals that the system is acceptable but needs some improvements.

$$\tilde{f}_{saw} = w_{DA} \cdot \sum_{i=0}^{5} \widetilde{DA\_i} \cdot w_{DA\_i} + w_{RA} \cdot \sum_{i=0}^{2} \widetilde{RA\_i} \cdot w_{RA\_i} + w_{UE} \cdot \sum_{i=0}^{4} \widetilde{UE\_i} \cdot w_{UE\_i} \quad (2)$$

Table 5
Values of the criteria

	DA_0	DA_1	DA_2	DA_3	DA_4	DA_5	RA_0	RA_1	RA_2	UX_0	UX_1	UX_2	UX_3	UX_4
user 1	Very Good	Good	Very Good	Fair	Very Good	Good	Good	Good	Very Good	Very Good	Fair	Good	Very Good	Very Good
user 2	Good	Very Good	Very Good	Poor	Good	Fair	Good	Very Good	Good	Fair	Good	Fair	Good	Good
user 3	Very Good	Very Good	Very Good	Fair	Very Good	Poor	Fair	Very Good	Fair	Good	Good	Poor	Very Good	Very Good
user 4	Good	Very Good	Very Good	Good	Very Good	Very Good	Very Good	Very Good	Very Good	Fair	Good	Fair	Very Good	Good
user 5	Very Good	Good	Very Good	Poor	Very Good	Very Poor	Fair	Very Good	Good	Very Good	Fair	Fair	Very Good	Very Good
user 6	Very Good	Very Good	Very Good	Good	Good	Good	Very Good	Very Good	Fair	Poor	Very Good	Good	Very Good	Very Good
user 7	Very Good	Very Good	Good	Very Good	Good	Poor	Good	Very Good	Good	Very Good	Very Good	Fair	Very Good	Very Good
user 8	Good	Very Good	Very Good	Fair	Good	Good	Good	Good	Fair	Very Good	Fair	Very Good	Good	Good
user 9	Good	Good	Very Good	Poor	Very Good	Very Good	Fair	Very Good	Good	Fair	Very Good	Fair	Good	Very Good
user 10	Poor	Fair	Good	Fair	Very Good	Poor	Very Poor	Good	Fair	Good	Poor	Poor	Fair	Fair
user 11	Very Good	Very Good	Very Good	Fair	Good	Fair	Good	Very Good	Very Good	Poor	Good	Very Good	Very Good	Very Good
user 12	Very Good	Very Good	Good	Good	Good	Good	Good	Very Good	Good	Very Good	Good	Fair	Good	Good
user 13	Very Good	Very Good	Very Good	Good	Very Good	Good	Fair	Good	Good	Good	Very Good	Good	Very Good	Very Good

Table 6

Linguistic variables and fuzzy numbers

Linguistic term	Fuzzy number
Very Poor	(0,0,1)
Poor	(0,1,3)
Fair	(3,5,7)
Good	(7,9,10)
Very Good	(9,10,10)

Table 7

Fuzzy numbers of the criteria

DA_0	(7.69,9.00,9.46)
DA_1	(8.08,9.38,9.77)
DA_2	(8.54,9.77,10.0)
DA_3	(4.00,5.69,7.23)
DA_4	(8.08,9.54,10.0)
DA_5	(4.54,6.00,7.23)
RA_0	(5.54,7.23,8.38)
RA_1	(8.38,9.69,10.0)
RA_2	(6.23,8.00,9.08)
UX_0	(5.77,7.23,8.23)
UX_1	(6.15,7.77,8.77)
UX_2	(4.38,6.08,7.54)
UX_3	(7.92,9.31,9.77)
UX_4	(7.92,9.31,9.77)

6. **Compute a crisp value.** A value is calculated for a system using a defuzzification method. Four defuzzification methods are most commonly used: the centroid method, mean of maximal (MOM), a-cut method and signed distance method (Zhao & Govind, 1991; Yager & Filev, 1994; Tsaur et al., 1997; Tang et al., 1999; Yao & Wu, 2000; Chou et al., 2008). All these methods share advantages and disadvantages (Klic & Yan, 1995), but Yao & Chiang (2003) propose the signed distance method, which is also used by Chou et al. (2008) in fuzzy SAW. The crisp total scores of individual locations are calculated by the following defuzzification equation:

$$d(\tilde{f}_i)=\frac{1}{3}(a_i+b_i+c_i),\ i=1,2,...,m \qquad (3)$$

where $d(\tilde{f}_i)$ gives the defuzzified value (crisp value) of the total fuzzy score of the system being evaluated. The closer the value is to 10 the more usable the system is. The defuzzified value is calculated as follows:

$$d(\tilde{f}_{saw}) = \tfrac{1}{3}(4.98 + 6.15 + 6.83) = 5.99 \qquad (4)$$

A mediocre system would have a value of 5. Since the value of $d(\tilde{f}_{saw})$ is around 6, the defuzzified value confirms the evaluation of the system using a fuzzy number. The fuzzy number calculated in the previous step to evaluate the system was estimated between 'Fair' and 'Good'. As a result, the system is rated as 'Medium Good'.

Discussion and Conclusions

This research work was targeted to assist visually impaired people in absorbing valuable information during the real-time progress of a live football match using a selves-developed tactile interface. To achieve that, high precision 3D modelling and printing systems were deployed for pitch mapping consistency so as to ensure the validity of both the verbally described and the tactile actions performed upon it simultaneously. Static tactile representations were selected to be asserted within the interface environment and height was mostly used, rather than depth, as the discriminating factor for the user to home-in on certain action tactile features. The latter, though, was favored for indicating and safely discriminating the significantly denser faithful mappings of the football pitch layout within both penalty areas of the high precision 3D model.

The methodology followed in this research was based on a holistic approach. It combined a number of creative tools, in order to explore, visualize and evaluate the proposed solutions, with advanced CAD modeling, rendering techniques, and 3D printing technology for improved representation and prototyping of the final product. The aim was to provide a worthy perceived experience that was incorporated from the beginning of the project, at the center of the users' needs and perspectives. In this way, visually impaired people are able to use the final product with a great deal of success and "feel the view" and the "time" in a variety of cases. Although the initial target was a great and difficult challenge from the design point of view, the designed product and its results from the evaluation phase, proved encouraging for the future of designing for visually impaired users.

The results of the evaluation revealed that the system is rated as 'Medium Good'. This means that the system is quite usable and could be used to assist the visually impaired in absorbing valuable information regarding the real time progress of a live soccer event using a selves-developed tactile interface.

However, the evaluation also revealed the aspects that could be improved. These aspects involved the user experience while using the system. More specifically, the criteria of User Experience (UX) are considered as the most important as UX has the highest weight. In the particular example, the first three criteria of User experience had lower values than the others criteria. Those values affected a lot the final values of the evaluation since the weight of UX was high. Therefore, it is among our future plans to improve

the invasiveness, the natural expression of action and the cognitive load required to use the system.

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Validation of a preliminary competency assessment scale for Malaysian graphic design graduates

ABSTRACT

The criteria for measuring the competency levels of graphic design (GD) graduates have continuously been shaped by the changing context of practice. However, previous studies provide little evidence on the existence of an effective competency assessment scale for GD graduates. The purpose of the study is to evaluate the psychometric properties of a preliminary competency assessment scale for GD graduates in Malaysia. 207 final year GD degree students in Malaysia were sampled to validate the scale. The data was analysed using exploratory factor analysis and Cronbach's reliability test. The results suggested that the preliminary scale consists of 12 constructs and 59 items under five competency dimensions. All 12 constructs yielded high internal consistency values, ranging between .723 and .914. Theoretically, the validated scale contributed to a new body of knowledge to the competency assessment of GD graduates in Malaysia. Practically, the findings provided relevant stakeholders with prescribed standards of performance and appropriate tools to assess the competency levels of new entrants to the GD profession.

KEY WORDS
Competency assessment scale, graphic design graduates, exploratory factor analysis, validity and reliability, Malaysia

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Introduction

There is no argument that the context for the practice of graphic design (GD) today has changed internationally. Emerging trends such as digital transformation, increasing complexity of design problems, dynamic shifts of the global economy, and divergence in people's preferences and behaviours have significantly expanded the job scope and possible career pathways of the practitioners (The American Institute of Graphic Arts [AIGA], 2015, 2021). No longer just work as craftsmen or decorators, contemporary graphic designers are accountable for creating viable, ethical, and effective design solutions by actively engaging themselves in interdisciplinary teams. Designers with relevant competencies to deal with these new patterns of practice are in demand in the global employment market (Dziobczenski, Person & Meriläinen, 2018; Google et al., 2017; AIGA et al., 2019).

As such, the education of graphic designers has been called to go beyond the conventional scope of technical training to produce well-qualified graduates who can meet the evolving expectations of industry practice (Davis, 2017; Heller, 2015). A number of attempts have been carried out in different countries, such as India (Ramneek, 2017; Taneja, 2021), United Kingdom (Dziobczenski & Person, 2017), Brazil (Dziobczenski et al., 2018), Ghana (Adu, 2015; Opoku, Appiah & deGraft-Yankson, 2020), Finland (Dziobczenski et al., 2018), United States (Bridges, 2016; D'Amico, 2018;

Google et al., 2017; AIGA et al. 2019), and Hong Kong (Cheung, 2016) to identify the knowledge, abilities, skills, and qualities required by new entrants to the GD profession. In general, these studies implied that GD graduates are expected to demonstrate a clear evidence of additional knowledge and skills, such as business and marketing awareness, creative thinking, communication, teamwork, project management, problem-solving, strategic thinking, emotional intelligence, adaptability, and so forth when starting their professional careers.

GD is a popular discipline in Malaysia. According to Ong (2017), the number of design students in Malaysia increased gradually between the year 2000 to 2010, from 8,000 to 10,000 each year, and it is believed that the number will be growing (Ong, 2017). This phenomenon has contributed to the prevalence of GD graduates in the workforce.

However, some scholars have expressed their concerns about the design education system in Malaysia and the 'outcomes' it produces. Debbie (2011) conducted interviews with prominent industry professionals found out that higher educational institutions (HEIs) "are not producing graduates who are fit for the industry" (p. 140) and that "the design education in many Malaysian institutions is still very much based on 'spoon-fed' system" (p. 149). The competency levels of GD graduates vary between institutions due to the lack of standardisation within the design education system in Malaysia (Debbie, 2011). Lim (2015) mentioned that the curricula of the design-related programmes in Malaysia, including GD, are very 'skill-oriented'. He agreed that most graduates are well-versed in producing good-looking works to meet the demands of the industry. However, they are not trained to respond to the real needs of society and lack of the capability to develop innovative products or strategies to drive economic growth. Since most of the Southeast Asian nations are putting more attention on the design to gain a competitive edge in the region, Lim (2015) suggested that design and entrepreneurial thinking must be included in design curricula in Malaysia to develop graduates' ability to "see business potentials, develop new markets, generate effective business plans, engage in market research, identify competitive advantages of their brands, conduct risk management, and make decisions" (p. 60). Rahman (2013) shared similar views and suggested a new direction of educating future designers in Malaysia. As she highlighted,

> *design should be for the people and the society, to improve the livelihood, encouraging sustainability rather than short-term outcomes. For that, designers need to start thinking creatively and critically. This thinking does not come naturally. It has to be learned and to be practiced for it to become part of the designer's core value (Rahman, 2013:p.30).*

Wong, Idris and Tan's (2020) study surveyed 19 university-level design academics and 13 industry practitioners who specialise in visual communication design, digital and interactive design, and advertising design to identify the competencies required by new entrants to the GD profession in Malaysia. Their findings replicated the findings of previous studies in other countries and supported the views of the scholars as mentioned earlier. Teamwork and leadership, project management skills, marketing fundamentals, self-efficacy, advertising design skills, reflective thinking skills, communication skills, industry knowledge, emotional intelligence, and design fundamentals were ranked by the experts as the top 10 needed competencies by GD graduates in Malaysia. This means that the expectations of GD graduates in Malaysia are similar with the global practice, and therefore the key question here is whether what the Malaysian students learn in the university is what they are expected to perform in the practice.

To assure the quality of design graduates, the Malaysian Qualifications Agency (MQA), an accrediting body of academic programmes HEIs in Malaysia, has developed a set of programme standards to guide the development and implementation of Art and Design related programmes. All design programmes, are required to include the five clusters of learning outcomes (LOs), i.e., knowledge and understanding; cognitive skills; functional work skills with focus on practical skills, interpersonal skills, communication skills, digital skills, numeracy skills, and leadership, autonomy and responsibility; personal and entrepreneurial skills; and, ethics and professionalism, to ensure the graduates obtain the necessary knowledge and skills in design practice (Malaysian Qualifications Agency (MQA), 2017). The specific competencies that the design graduates will need to obtain upon the completion of their studies at bachelor's degree level are:

- Interpret and apply knowledge and skills including the use of numeracy techniques in relevant areas of Art and Design for innovative practices.
- Critically analyse historical, contextual, conceptual theories, and ethical judgment in Art and Design practice.
- Create and conceive ideation and innovation for the practice areas of art and / or design.
- Articulate and communicate ideas and concepts comprehensively in visual, written, and oral engagements.
- Execute design concept and cost analysis through the use of digital and other technologies for effective delivery.
- Construct a portfolio for Art and Design, through reflectivity, review, and evaluations.

- Communicate and interact with experts, peers, clients, superiors and society under work and organisational related environment for the development of art and / or design (Malaysian Qualifications Agency (MQA), 2020:p.15).

The criteria for measuring GD graduates' competencies have continuously been shaped by the rapidly changing technological, economic, cultural, social, and business demands (Higgins, 2008). According to Gonczi, Hager and Athanasou (1993:p.5), competency-based assessment can be described as "the process of determining whether a candidate meets the prescribed standards of performance, i.e. whether they demonstrate professional competence". The development of required competencies is a proactive response to the growing demand for accountability of GD education in recent years (Chiang, Idris & Chuen, 2018; Chiang, Idris & Chuen, 2019). Competency assessment is crucial to determine if the graduates are receiving a quality education with sufficient preparation for their future employment, professional careers in design, and personal lives (Davis, 2017; Dziobczenski et al., 2018). However, it is learned from the literature review that internationally, none of the existing studies (e.g., Ramneek, 2017; Taneja, 2021; Dziobczenski & Person, 2017; Dziobczenski et al., 2018; Adu, 2015; Opoku, Appiah & deGraft-Yankson, 2020; Bridges, 2016; D'Amico, 2018; Cheung, 2016) have gone beyond to develop a psychometrically sound measurement scale to provide a more feasible and holistic competency assessment solution for stakeholders involved in the educational or employability process of GD graduates. Locally, there is no easy and effective way to determine the competency levels of design graduates in Malaysia, specifically in GD related programmes. Although cumulative grade point average (CGPA) has long been using as an overall academic achievement indicator of all university graduates, including GD, there is very little scientific evidence to suggest that it can effectively predict their actual performance while working in the industry. Previous studies (e.g., Debbie, 2011) implied that local employers in GD industry are facing difficulties in recruiting qualified graduates to join their companies.

The challenge of assessing whether the graduates have achieved the expected competency levels cannot be overlooked. Such a challenge is inherent in the diverse and constantly changing nature of design practice. The key concern is on how to effectively measure if they have obtained the desired competencies in a rapidly changing work environment. In addition, the validity and reliability of the measurement tool must need to be carefully examined to ensure its accuracy. Therefore, the researchers of the study intend to tackle this challenge to fill the gap in the literature, specifically in the context of Malaysia.

Purpose of the study and research questions

Wong, Idris and Tan (2021) had conducted a study using modified Delphi technique to gain consensus among a collective of experts in Malaysia. A list of 29 competency constructs and 108 performance indicators under five major competency dimensions (CDs), i.e., cognitive competency dimension (CCD), functional competency dimension (FCD), personal competency dimension (PCD), ethical competency dimension (ECD), and meta-competency dimension (MCD) were identified. In other words, in the local experts' opinions, GD graduates are required to demonstrate the acquisition of these competency constructs and items for superior work performance. The study aims to evaluate the psychometric properties of the preliminary competency assessment scale that was previously developed by Wong, Idris and Tan (2021). Such attempt is essential and crucial because it can possibly minimise the measurement error and strengthen the accuracy of the scale. Accuracy, in this case, means that the assessment results are valid and reliable in measuring of the knowledge, skills, and abilities of university GD graduates. Correspondently, the research question of the study is: what is the validity and reliability evidence of the preliminary scale to measure the competency levels of new entrants to GD profession for each CD in Malaysia?

Methodology

Population and sampling

Final year GD students at the bachelor's degree level were the target population for the survey questionnaire. They were selected using simple random sampling technique. The eligible students must acquire three common characteristics: (1.) they are now in their final year of undergraduate studies; (2.) they are majoring in GD related programmes such as visual communication design, advertising design or digital and interactive design; and (3.) they are studying in either private or public higher educational institutions (HEIs) in Malaysia. The final usable sample size was 207.

Instrumentation

The survey questionnaire consists of five sections. Section One is a short introduction to the study. Section Two is an electronic informed consent form. Section Three comprises demographic questions such as the programme of study, ethnic group, and gender. Section Four is an instruction on how to answer the questionnaire. Section Five comprises a list of 108 items as shown in Table 1. These items were the performance

indicators of the 29 competency constructs developed by Wong, Idris and Tan (2021). The participants were requested to examine and reflect on the items and self-evaluate their competency levels based on a 5-point Likert scale as proposed by Dreyfrus and Dreyfus (1986), where: 1 = Novice; 2 = Advanced Beginner; 3 = Competent; 4 = Proficient; and 5 = Expert.

Prior to the field research, three scholars from the design field were invited to review the questionnaire. They were selected based on their integrated education and work experiences. The reviewers were asked to check whether the items adequately captured the content or not, and to examine the accuracy of the wording used. Besides, the survey questionnaire was distributed electronically to 40 final year GD degree students who studying at private or public HEIs in Malaysia. They are the target population of the study. 29 of them responded and completed the questionnaire.

The responses were calculated using Cronbach's reliability test. All constructs in the survey questionnaire demonstrated acceptable reliability values of .60 and above (Flynn, et al., 1990; Nunnally, 1978). In other words, all items were retained for actual field research.

Data analysis and results of the study

The data collected were analysed following a two-step procedure. First EFA was performed on the items with varimax rotation using Statistical Package for Social Science (SPSS) version 22. Specifically, principal component analysis (PCA) was applied as the factor extraction method. The analysis aims to evaluate the underlying structures of each CD and the appropriateness of the items. It involved an iterative estimation process to

Table 1

Competency constructs and items for GD graduates, developed by Wong, Idris and Tan (2021)

Competency Dimension	Construct		No. of Items
Cognitive Competency Dimension	Design Fundamentals		3
	Industry Knowledge		4
	Contextual Awareness		4
	Multidisciplinary Knowledge		2
	Business Fundamentals		3
	Marketing Fundamentals		3
		Total	**19**
Functional Competency Dimension	Technical Design Skills		3
	Conceptual Design Skills		4
	Interactive Design Skills		3
	Advertising Design Skills		3
	Software Skills		3
	Graphic Print Production Skills		4
	Project Management Skills		5
		Total	**25**
Personal Competency Dimension	Aesthetic and Visual Sensitivity		3
	Self-driven		3
	Adaptability and Flexibility		3
	Emotional Intelligence		4
	Interpersonal Skills		3
	Self-efficacy		3
		Total	**19**
Ethical Competency Dimension	Professional Behaviours		9
	Professional Expertise		5
	Professional Values		3
		Total	**17**
Meta-competency Dimension	Creative Thinking Skills		3
	Problem-solving Skills		3
	Design Thinking Skills		3
	Critical Thinking Skills		4
	Reflective Thinking Skills		4
	Communication Skills		7
	Teamwork and Leadership Skills		4
		Total	**28**

Source: Wong, Idris & Tan (2021)

reach the final solution. Factors with eigenvalue of 1 or greater were retained because they were deemed as valid factors (Field, 2013; Hair et al., 2010). All retained items must achieve loadings of .50 or greater to be considered as good representatives of a factor. Items that failed to contribute significantly to the extracted factors were deleted. Cross-loaded items were also eliminated. This is then followed by the application of Cronbach's Alpha Reliability Test to further assess and examine the internal consistency of the retained items.

Description of the sample

As presented in Table 2, the survey link managed to reach a total of 274 potential participants. However, six (2.2%) of them rejected to participate in the study. As tabulated in Table 3, of the 268 participants who initially agreed to participate in the study, 207 of them completed the questionnaire, representing 77.2% of overall completion rate.

Table 2

Overall participation rate for the survey questionnaire

Number of Participants Reached	Number of Participants Agreed to Participate in the Study	Overall Participation Rate (%)
274	268	97.8

Table 3

Overall completion rate for the survey questionnaire

Number of Participants Agreed to Participate in the Study	Number of Completed Questionnaire	Overall Completion Rate (%)
268	207	77.2

Demographic analysis

This section provides an overview of the demographic profiles of the respondents, as presented in Table 4. Based on the collected data, respondents from private HEIs slightly outnumber respondents from public HEIs, accounting for 50.7 percent as against 49.3 percent, respectively. Most respondents are majoring in visual communication design (43%), followed by digital and interactive design (31.9%), and advertising design (25.1%). From the ethnic group, the Chinese occupied the highest percentage (53.6%), followed by Malay (40.1%), and others (6.2%). 43 percent of the respondents are male, and 57 percent are female.

Descriptive statistics

Prior to executing EFA, the accuracy of the data entry, missing values, normality, and outliers were thoroughly reviewed. Skewness and kurtosis coefficients were also examined. Results revealed that the mean scores of the constructs ranged between 2.786 and 3.376. The construct that obtained the highest mean score was 'teamwork and leadership skills', and the lowest one was 'business fundamentals'. Standard deviation scores remained at .846 or below, indicating that all scores were close to the average. The minimum and maximum values for all constructs were the same, ranged from one to five. The skewness values ranged between -.737 and .229, while the kurtosis ranged from-.697 to .580. The obtained values were within the acceptable range of-2.0 to +2.0, suggesting that all items were normally distributed (Field, 2013; Garson, 2012). All these indicators suggested that the collected data were suitable for further analysis because no significant violation was discovered in the descriptive statistics.

Table 4

Frequency and percentages of respondents' information (N = 207)

	Variable	Frequency	Percent (%)
Study at	Private higher educational institution	105	50.7
	Public higher educational institution	102	49.3
Major in graphic design study	Visual communication design	89	43.0
	Advertising design	52	25.1
	Digital and interactive design	66	31.9
Race	Malay	83	40.1
	Chinese	111	53.6
	Indian	3	1.4
	Dusun, Kadayan, and Iban	6	2.9
	Others (e.g., Iraqi, Filipino, and Pakistani)	4	1.9
Gender	Male	89	43.0
	Female	118	57.0

EFA: Validity of the scale

Cognitive competency dimension

Table 5 displays the results of KMO and Bartlett's test of sphericity for CCD. The obtained KMO value was .950, fulfilling the required value of .60 (Field, 2013; Kaiser, 1960). The Bartlett's test of sphericity, χ^2 (171) = 2506.901, $p < .05$, suggesting that correlations between items were significantly large for factor analysis (Hair et al., 2010). All communalities were greater than .40 (ranged between .419 and .700), indicating that the items were well defined by the factor solution.

Table 5

KMO and Bartlett's Test of Sphericity results for cognitive competency dimension

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		.950
Bartlett's Test of Sphericity	Approx. Chi-Square	2506.901
	df	171
	Sig.	.000

An initial analysis was run to obtain eigenvalues for each factor in the data. Surprisingly, two factors were found to have eigenvalues greater than one. The results suggested that two extracted factors accounted for 59.242 percent of total variance explained in the constructs analysed. In specific, the first factor explained 53.319 percent of the variance, while second one explained 5.923 percent. All items in CCD had loadings of .40 or greater.
However, a total of 11 items were eliminated for exhibiting factorial complexity on two factors (Tabachnick & Fidell, 2007). After the deletion of the items, further analysis was performed on the retained eight items. Table 6 presents the extracted factors along with their items for CCD. This two-factor structure was found to be accounted for 67.009 percent of total variance explained. While the factor one explained 53.771 percent of the variance, factor two explained 13.238 percent. The anti-image correlations ranged between .827 and .911, satisfying the requirement of .50 and above.

Factor one, which was initially labelled as 'business fundamentals', contained three hypothesised items. Interestingly, these three items were loaded substantially under this factor. However, an item 'identify current marketing trends about the targeted market segment', which was originally hypothesised on different factor, was loaded under factor one. The loadings of this item demonstrated practical and statistical significance (Hair

Table 6

Cognitive competency dimension factor loading, eigenvalues, variance explained, anti-image, means, and standard deviation scores

No.	Item	Factor Loading		MSA	Mean	SD
		Factor One	**Factor Two**			
1	Justify solutions to business problems after examining relative costs and benefits of all potential solutions.	.875		.832	2.749	.946
2	Recognise the role of relevant professionals in the functioning of a business.	.781		.869	2.855	.970
3	Identify current marketing trends about the targeted market segment.	.752		.868	2.971	1.024
4	Understand what makes a business to be profitable.	.739		.904	2.754	1.039
5	Understand how design elements and principles are useful for constructing meaningful visuals.		.868	.827	3.290	.931
6	Comprehend the standards of good typography.		.703	.882	3.116	.912
7	Demonstrate an in-depth understanding of design thinking and process.		.687	.869	3.048	.817
8	Understand the connections between graphic design and sociology, psychology, and other relevant disciplines.		.657	.911	2.990	.914
Initial Eigenvalues	**Total**	4.302	1.059			
	% of Variance	53.771	13.238			
	Cumulative %	53.771	67.009			

Note: Extraction Method: Principal Components Analysis. Rotation Method: Varimax with Kaiser Normalization.
MSA = Measures of Sampling Adequacy (Anti-image Correlation). SD = Standard Deviation

et al., 2010). Since this study keens on seeking for an empirical exploration rather than a theoretical solution, therefore, this item was retained in factor one. To describe the meaning of all items more effectively, this factor was relabelled as 'commercial awareness'.

Pertaining to factor two, which was labelled as 'design fundamentals', three items were originally hypothesised on this factor. All three items were loaded accurately under this factor. However, an item that was initially indexed on another factor, was loaded on this factor. This item was 'understand the connections between graphic design and sociology, psychology, and other relevant disciplines. With the same reason as stated above, this item was retained in factor two. Consequently, factor two was relabelled as 'integrated design knowledge' to better represent the overall meaning of the items.

Functional competency dimension

A summary of the results of KMO and Bartlett's test of sphericity for functional competency dimension is presented in Table 7. The sample size was deemed as sufficient to examine the factor structure because the KMO measure of sampling adequacy yielded a value of .950. The appropriateness of the data for factor analysis was supported the Bartlett's test of sphericity, χ^2 (300) = 3377.989, $p < .05$. Furthermore, communalities for each item were determined. It was found that the results ranged from .503 to .727.

Table 7

KMO and Bartlett's Test of Sphericity results for functional competency dimension

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		.950
Bartlett's Test of Sphericity	Approx. Chi-Square	3377.989
	df	300
	Sig.	.000

Three factors were found to have eigenvalues greater than one in FCD. These three extracted factors explained 60.510 percent of the variance. Each factor explained 50.209 percent, 5.276 percent, and 5.026 percent of the variance, respectively. Based on the results, all items met minimum factor loadings of .40 or above. However, a total of 11 items were discarded because they were cross loaded on two factors. Accordingly, 14 items were retained in FCD for further analysis. The results revealed that the three-factor structure accounted for 65.754 percent of total variance explained. Each factor explained 49.866 percent, 8.568 percent, and 7.320 percent of the variance, respectively. The anti-image correlations for all the items in FCD were above .50, ranging between .883 and .966. Table 8 displays the analysis results for FCD.

Factor one was a 'newfound' factor. There were eight items, which originally hypothesised on different factors, were loaded on this factor substantially. Their loadings ranged between .574 and .810. A closer examination of these items revealed that they represent the abilities to perform and manage day-to-day design process and tasks in the industry. As such, factor one was labelled as 'operational design process management skills'.

Factor two was originally labelled as 'graphic print production skills' that contained four items. Of the four items initially hypothesised on this factor, three items showed statistical significance of loadings (Hair et al., 2010). One item was discarded due to cross-loading issue. Three items were initially hypothesised on factor three, which was labelled as 'software skills'. Interestingly, all three items were accurately and significantly loaded under their hypothesised factor. No factorial complexity or low loading issues were found in association with this factor.

Personal competency dimension

Details of Kaiser-Meyer-Olkin measure of sampling adequacy and Bartlett's test of sphericity results for PCD is tabulated in Table 9. The KMO yielded an ideal value of .945, while the Bartlett's test demonstrated statistically significant results, χ^2 (171) = 2444.515, $p < .05$. It was also found that the results of the communalities for each item ranged from .496 to .825.

An initial analysis was run to obtain eigenvalues for each factor in PCD. Only two factors were found to have eigenvalues greater than one. The two extracted factors accounted for 59.079 percent of total variance explained. In specific, the first factor explained 51.938 percent of the variance, while second one explained 7.141 percent. The loadings of all items in PCD were .40 or greater, ranged between .440 and .891. Nevertheless, the six items as listed below were eliminated due to cross loading issue. A further analysis of the retained 11 items revealed that the two-factor structure accounted for 62.299 percent of total variance explained. Each factor explained 52.028 percent and 10.271 percent of the variance, respectively. The anti-image correlations for all the items were above .50, ranging from .858 to .947. Table 10 displays the analysis results for PCD.

Factor one was a new established factor. Besides four items that initially hypothesised on 'emotional intelligence' were loaded substantially on factor one, interestingly, additional six items were also loaded on this factor. When examined more closely, it was found that all these items were interrelated, reflecting the ability of individuals to make sense of their own and others' personality, and to use this information to

Table 8

Functional competency dimension factor loading, eigenvalues, variance explained, anti-image, means, and standard deviation scores

No.	Item	Factor Loading			MSA	Mean	SD
		Factor One	Factor Two	Factor Three			
1	Assure the quality of the project deliverables at a minimal risk.	.810			.924	3.019	.990
2	Develop functional concepts to visualise intended messages or ideas.	.767			.940	3.068	.943
3	Conceptualize big idea to guide the focus of advertising efforts.	.762			.930	3.073	.955
4	Set priorities right to effectively handle multiple tasks according to their urgency.	.727			.940	3.232	.895
5	Develop creative advertising content for a campaign to achieve persuasive communication.	.710			.926	2.952	.907
6	Produce sketches, mock-ups, mood boards, mind maps, or other relevant visuals to clarify design specifications.	.626			.966	3.416	.925
7	Apply consistent art direction across a wide range of graphic media.	.616			.956	3.150	.860
8	Anticipate how users will interact with the graphical interface.	.574			.937	2.903	.875
9	Apply appropriate print finishing techniques to achieve desired outcomes.		.847		.883	2.879	.924
10	Liaise with printers to identify printing requirements.		.741		.911	2.768	1.068
11	Pre-flight print ready digital files for the intended output.		.720		.942	2.845	.958
12	Acquire video and audio software skills for time-based media production.			.767	.912	3.019	1.136
13	Possess up-to-date UI, UX, and other related software skills for websites, web-based applications, and mobile applications design.			.766	.902	2.473	1.051
14	Master essential graphic design software skills for effective image and layout manipulation.			.646	.944	3.208	.887
Initial Eigenvalues	**Total**	6.981	1.199	1.025			
	% of Variance	49.866	8.568	13.238			
	Cumulative %	49.866	58.434	65.754			

Note: Extraction Method: Principal Components Analysis. Rotation Method: Varimax with Kaiser Normalization.
MSA = Measures of Sampling Adequacy (Anti-image Correlation). SD = Standard Deviation

guide their actions and attain better results. As such, factor one was labelled as 'personal intelligence'.

Table 9

KMO and Bartlett's Test of Sphericity results for personal competency dimension

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		.945
Bartlett's Test of Sphericity	Approx. Chi-Square	2444.515
	df	171
	Sig.	.000

Regarding factor two, which was labelled as 'aesthetic and visual sensitivity', three items were originally hypothesised on this factor. Interestingly, all three items were loaded accurately and substantially under this factor with no factorial complexity and low loading issues.

Ethical competency dimension

The results of the KMO and Bartlett's test for ECD are demonstrated in Table 11. A value of .910 was obtained for KMO, exceeding the required value of .60, and Bartlett's test produced statistically significant results, χ^2 (136) = 1603.691, $p < .05$, verifying the factorability of the

Table 10

Personal competency dimension factor loading, eigenvalues, variance explained, anti-image, means, and standard deviation scores

No.	Item	Factor Loading		MSA	Mean	SD
		Factor One	Factor Two			
1	Demonstrate self-control while confronting conflicts at workplace.	.757		.930	3.377	.921
2	Take initiative to seek feedback from co-workers for further improvement.	.749		.922	3.377	.926
3	Use mistakes as part of the learning process.	.745		.903	3.628	.936
4	Being flexible while interacting with others.	.738		.932	3.329	1.023
5	Adjust actions to deal with changing or unanticipated circumstances.	.713		.960	3.188	.880
6	Self-examine own capabilities truthfully.	.709		.934	3.382	.921
7	Handle constructive criticism gracefully.	.696		.943	3.130	.939
8	Recover quickly from setbacks.	.681		.947	3.198	.963
9	Being sensitive to behaviours of others.	.678		.921	3.348	.962
10	Display optimism when handing stressful work situations.	.629		.937	3.304	1.014
11	Make sound aesthetic judgment in design process.		.894	.858	3.155	.868
12	Demonstrate creative flair in developing artistic ideas.		.849	.871	3.111	.925
13	Show a good standard of art appreciation.		.803	.891	3.420	.967
Initial Eigenvalues	**Total**	6.764	1.335			
	% of Variance	52.028	10.271			
	Cumulative %	52.028	62.299			

Note: Extraction Method: Principal Components Analysis. Rotation Method: Varimax with Kaiser Normalization. MSA = Measures of Sampling Adequacy (Anti-image Correlation). SD = Standard Deviation

collected data. The communalities of the items remained at .40 or greater, ranged between .445 and .778.

Table 11

KMO and Bartlett's Test of Sphericity results for ethical competency dimension

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		.910
Bartlett's Test of Sphericity	Approx. Chi-Square	1603.691
	df	136
	Sig.	.000

Based on the results of the initial analysis, it was found that ECD constituted of three factors with eigenvalues greater than one. These three extracted factors in ECD explained 58.272 percent of the variance. Each factor explained 42.978 percent, 8.097 percent, and 7.197 percent of the variance, respectively. A total of six items were omitted for showing cross loading and low loading issues. A further analysis was conducted on the 11 items retained in ECD. The results suggested that the three-factor structure accounted for 64.830 percent of total variance explained. Each factor explained 44.044 percent, 11.554 percent, and 9.231 percent of the variance, respectively. The anti-image correlations for all the items ranged from .789 to .927. A summary of the factor analysis results for ECD is tabulated in Table 12.

Factor one, which represented 'professional expertise', was originally constituted five items. All five items were loaded substantially and practically on their hypothesised factor showing neither cross-loading nor low loading issues in relation to the factor.

With regards to factor two, which was labelled as 'professional behaviours', nine items were originally hypothesised on this factor. However, only four items that demonstrated significant loadings were retained. Of the five discarded items, three items were found to have factorial complexity issue and the other two items faced low loading issue. Factor three contained two highly loaded items. Originally, this factor was labelled 'professional values' with three hypothesised items. One item was omitted for showing factorial complexity.

Table 12

Ethical competency dimension factor loading, eigenvalues, variance explained, anti-image, means, and standard deviation scores

No.	Item	Factor Loading			MSA	Mean	SD
		Factor One	Factor Two	Factor Three			
1	Provide professional guidance to clients about the sustainability of commercial activities.	.864			.810	2.957	.987
2	Minimise wastage through interpreting projects innovatively.	.812			.855	3.024	.916
3	Create graphic design solutions that can facilitate people's participation in civic life.	.633			.927	2.986	.906
4	Aware of essential labelling requirements for consumer products or packages.	.608			.920	3.217	.938
5	Make reasonable choices when designing a graphic artefact.	.569			.900	3.251	.833
6	Reject all type of plagiarism.		.755		.851	3.464	1.100
7	Describe own capabilities honestly.		.755		.902	3.502	.985
8	Make appropriate acknowledgement of authorship when others have co-created a design.		.715		.858	3.309	.971
9	Treat all designers with respect in fair competition.		.678		.875	3.705	.943
10	Refuse to engage in any type of discrimination.			.836	.789	3.406	1.033
11	Refuse to use deceptive marketing messages to promote products or services.			.833	.806	3.174	.929
Initial Eigenvalues	**Total**	4.845	1.271	1.015			
	% of Variance	44.044	11.554	9.231			
	Cumulative %	44.044	55.598	64.830			

Note: Extraction Method: Principal Components Analysis. Rotation Method: Varimax with Kaiser Normalization. MSA = Measures of Sampling Adequacy (Anti-image Correlation). SD = Standard Deviation

Meta-competency dimension

Table 13 presents the results of KMO and Bartlett's test for MCD. The obtained KMO value was .954, fulfilling the minimum required value of .60. Further, the Bartlett's test, χ^2 (378) = 3758.393, $p < .05$, suggesting that correlations between items were significantly large for factor analysis. All communalities were greater than .40, ranged between .442 and .671.

Table 13

KMO and Bartlett's Test of Sphericity results for meta-competency dimension

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		.954
Bartlett's Test of Sphericity	Approx. Chi-Square	3758.393
	df	378
	Sig.	.000

An initial analysis was run to obtain eigenvalues for each factor in MCD. Two factors demonstrated eigenvalues of one or greater. The results indicated that two extracted factors accounted for 59.242 percent of total variance explained in the constructs analysed. Specifically, the first factor explained 53.319 percent of the variance, while second one explained 5.923 percent. Based on initial results of the analysis, a total of 15 items were omitted due to cross loading and low loading issues (Tabachnick & Fidell, 2007). Further analysis was run on the retained 13 items. Table 14 presents the extracted factors along with their items for MCD. This two-factor structure was found to be accounted for 60.437 percent of total variance explained. While the factor one explained 50.713 percent of the variance, factor two explained 9.724 percent. The anti-image correlations ranged between .897 and .965, fulfilling the requirement of .50 and above.

Six items originally indexed on different factors were loaded substantially on factor one in MCD. When examined more closely, it was found that all these items were interrelated, reflecting the capability of individuals to handle design or work-related problems creatively and critically. Consequently, factor one was labelled as 'analytical and creative problem-solving skills' to better represent the meanings of all the items.

Table 14

Meta-competency dimension factor loading, eigenvalues, variance explained, anti-image, means, and standard deviation scores

No.	Item	Factor Loading		MSA	Mean	SD
		Factor One	Factor Two			
1	Use evidence skillfully to justify decisions made.	.797		.938	3.222	.886
2	Avoid making biased judgments when lacking of robust evidence.	.745		.927	3.304	.950
3	Transfer learning between contexts effectively.	.741		.931	3.077	.827
4	Develop successful solutions to a problem by using up-to-date information.	.737		.914	3.058	.943
5	Devise clever ways to carry out design or related work tasks.	.709		.912	3.101	.827
6	Generate a number of original ideas through capturing unexpected insights.	.654		.965	3.145	.980
7	Select right channels to communicate with internal or external project stakeholders.		.760	.905	3.068	.873
8	Lead team members to deliver desired results.		.760	.931	3.213	1.011
9	Work productively in interdisciplinary teams to attain desired results.		.739	.942	3.237	.874
10	Speak in a manner that is clear, coherent, and concise.		.701	.960	3.203	.949
11	Appreciate the value of team diversity through respecting the backgrounds, talents, and opinions of others.		.701	.955	3.643	.886
12	Capture the main points of what others speak.		.693	.897	3.348	.906
13	Build a positive working climate to enhance teamwork experience.		.616	.925	3.411	.926
Initial Eigenvalues	**Total**	6.593	1.264			
	% of Variance	50.713	9.724			
	Cumulative %	50.713	60.437			

Note: Extraction Method: Principal Components Analysis. Rotation Method: Varimax with Kaiser Normalization.
MSA = Measures of Sampling Adequacy (Anti-image Correlation). SD = Standard Deviation

Factor two contained seven items that originally hypothesised on two different factors. Specifically, three items were from 'communication skills' and four items were from 'teamwork and leadership skills'. This pool of items showed practical and statistical significant loadings on factor two. To better illustrate the meanings of all these items represented, consequently, factor two was labelled as 'interdisciplinary collaboration skills'.

Cronbach's Alpha: Reliability of the scale

Field (2013) recommended that one of the crucial steps for researchers to do after factor analysis is to check whether the scale is reliable. Reliability refers to the consistency of the items in producing similar results under different situations (Kimberlin & Winterstein, 2008; LeCompte & Goetz, 1982). To achieve a good reliability, the generally accepted Cronbach's alpha value is .70 or higher (Hair et al., 2010). However, Nunnally (1978) and Flynn et al. (1990) suggested that a reliability value of .60 or above enough for a new scale. Details of reliability statistics for each construct are presented in Table 15.

All constructs in this scale obtained relatively high internal consistency. All the values were above .70, ranging between .723 and .914. The construct that achieved the highest reliability value was 'personal intelligence', while the lowest one was 'software skills'.

Discussion

This section discusses the five competency dimensions and the retained items after the analysis. Cognitive competencies refer to the acquisition of relevant knowledge, awareness or understanding, and the capability to apply these effectively in work-related situations (Cheetham &

Table 15

Reliability statistics for the constructs in each competency dimension

Dimension	Construct	Cronbach's Alpha		No. of Items
Cognitive Competency Dimension	Commercial Awareness	.854		4
	Integrated Design Knowledge	.793		4
			Total	**8**
Functional Competency Dimension	Operational Design Process Management Skills	.903		8
	Graphic Print Production Skills	.819		3
	Software Skills	.723		3
			Total	**14**
Personal Competency Dimension	Personal Intelligence	.914		10
	Aesthetic and Visual Sensitivity	.873		3
			Total	**13**
Ethical Competency Dimension	Professional Expertise	.817		5
	Professional Behaviours	.797		4
	Professional Values	.746		2
			Total	**11**
Meta-competency Dimension	Analytical and Creative Problem-solving Skills	.884		6
	Interdisciplinary Collaboration Skills	.860		7
			Total	**13**

Chivers, 1996; Cheetham & Chivers, 1998). The findings showed that there are two constructs in CCD, namely 'commercial awareness' and 'integrated design knowledge'. Each construct has four performance indicators. In general, design as a discipline can be applied broadly across business function (Conley, 2004). A recent survey indicated that graphic designers in the United States have a strong interest in business-related knowledge (Google et al., 2017). On the one hand, the designers want to strengthen the business operation and marketing of their companies. On the other hand, they intend to offer strategic business development services for their clients. Such kind of services may include proposing innovative ideas to clients with regards to the internal systems of their businesses, product and service offerings, and consumer experience (Keeley, 2013). Therefore, it is no surprise that 'commercial awareness' was identified as a vital area of understanding for GD graduates in this study, which is in consistent with previous studies (e.g., Pirotti & Venzin, 2016; D'Amico, 2018; Dziobczenski & Galeotti, 2017).

The young practitioners are unlikely to be able to fulfil the demands of commercial clients in a competitive marketplace if they only know how to produce beautiful crafts (AIGA, 2015; Cheung, 2016). In addition, long-established knowledge in a discipline is always essential for employment in most industries (Ramírez, 2012). Therefore, any graduate of a GD programme is expected to possess a good understanding of design elements, principles, and thinking process to produce layout for various types of media (D'Amico, 2018). Apart from the 'traditional knowledge', interestingly, one of the performance indicators implied that GD graduates in Malaysia should also acquire knowledge from a broad range of disciplines. This simply means that young practitioners need to learn more than they once had to learn.

Functional competencies refer to the ability to perform a variety of work-related tasks using available technologies and tools to achieve specific outcomes (Cheetham & Chivers, 1996; Cheetham & Chivers, 1998). The findings suggested that GD graduates in Malaysia are expected to possess a varied skill set in areas ranging from operational design process management to software and graphic print production. There is a typical series of tasks that graphic designers perform in the design process to produce technically and conceptually sound visual solutions. Interestingly, these tasks were represented by the indicator (1) to (6) – from user investigation to idea generation, content development, concept visualisation, and design actualisation. Since the 'traditional' role of GD is to create functional and beautiful visuals to communicate messages and information (Cezzar, 2017), this explains why operational design skills are perceived as highly important by employers of graphic designers in Brazil (Dziobczenski et al., 2018), United Kingdom (Dziobczenski & Person, 2017), and United States (Bridges, 2016). Similarly, these findings also align with the survey results conducted by Bohemia (2002) that employers mainly search for operational contributions from industrial designers, such as to enhance the physical look of the products. As also implied by the indicator (7) and (8), the design process needs to be managed effectively and efficiently. Past studies (e.g., D'Amico, 2018; Dziobczenski & Galeotti, 2017) showed that GD graduates who can adhere to deadlines, establish priorities while handling multiple tasks, work within resource constraints, and always assure the quality of the project deliverables are expected to have an advantage while seeking employment. Moreover, software skills are needed for every GD gradu-

ate to create commercially and professionally acceptable works. The quality of the design outcomes or deliverables depends highly on the ability of a designer in performing the required software. The results of this study, coupled with the findings of past studies on software skills, indicated that the operational roles of graphic designers, i.e., to produce visually appealing design, remain important in the practice. The challenge for GD education is to produce versatile graduates who can deliver both print and digital materials with up-to-date software skills to fulfil the demands. GD was traditionally viewed as a discipline that centred on printing (Neves, 2017). While contemporary graphic designers are encouraged to place more emphasis on producing digital design in a world that is increasingly digitalised, the findings demonstrated that print design is still having, and will continue to have its place today. The skills in the print production area cannot be overlooked while educating GD graduates.

Personal competencies refer to the acquisition of appropriate and observable social behaviours, desires, psychological impulses or emotions in work-related situations (Spencer & Spencer, 1993). Based on the results of the analysis, there are two constructs in this dimension, namely 'personal intelligence' and 'aesthetic and visual sensitivity'. The two constructs are represented by 10 and four performance indicators, respectively. 'Personal intelligence' is defined by Mayer (2008) as the capability to justify and use personal information or personality to strengthen individual's beliefs, actions, and life experiences. Ramneek's (2017) study suggested that as the world of GD becomes more complex and harder to be defined and future is seeking for young practitioners who are aggressive, resilient, and compassionate, and can adapt and learn quickly. Specifically, he urged designers to display empathy for others as part of the adaptability process because it may help them to successfully handle conflicts, work in teams, align interests, listen effectively, make decisions, solve problems, and drive change. On the other hand, GD is transforming from a craft-oriented profession into a discipline that is focused more on conceptualisation, development, and implementation of innovative ideas for problem-solving. As discussed earlier, the integration of knowledge from other disciplines is particularly important in this process. However, this does not mean that GD should abandon its very own heritage (Muratovski, 2016). Friedman (2012) argued that successful design is a marriage between craft-oriented and scientific ways of working. This argument means that it is also essential for graphic designers to cultivate a good artistic sensitivity to make sound aesthetic judgment in the design process (Dziobczenski & Person, 2017).

Despite ethics and values are crucial for professional design practice and development, McCollam (2014) claimed that they have always been overlooked in the education of graphic designers. Likewise, previous qualitative studies by Chiang et al. (2016) and Chiang et al. (2019) suggested that social responsibility of graphic designers in social, cultural, and environmental dimension was not extensively integrated into GD curricula in Malaysia. In adding to these discussions, the findings of the present study further reinforced the importance of educating ethically-minded graphic designers. In this study, ethical competencies can be described as the appropriate personal and professional values and the capability to make sound judgments based on these in given work-related contexts (Cheetham & Chivers, 1996; Cheetham & Chivers, 1998). The findings demonstrated that there are three constructs constitute of ECD. They are: 'professional expertise' (5 items), 'professional behaviours' (4 items), and 'professional values' (2 items).

Meta-competencies are those generic and overarching 'soft-qualities' (Boak & Coolican, 2001) that deeply embedded in learning and that enabling introspection and self-assessment (Brown & McCartney, 1995). They are of a higher level than other competencies and able to support the acquisition and development of other competencies. There are two constructs in this dimension, namely 'analytical and creative problem-solving skills' and 'interdisciplinary collaboration skills'. Each construct contains six and seven performance indicators, respectively. The job of a graphic designer has become increasingly challenging and important as a result of the development of global communication and advancement of technology. In response to this, the ability of graphic designers to apply analytical and creative thinking skills in the design or day to day working process to solve problems, make sound decision, and generate workable solutions are also becoming more important (Ciampa, 2010). Furthermore, 'communications skills' and 'teamwork and leadership skills' were discussed separately in most of the previous studies (e.g., Dziobczenski & Person, 2017), but surprisingly, these two skills were combined to form a bigger competency area in this study. A closer examination of the findings demonstrated that the indicator (1), (2), and (3) represent 'communication skills', while the indicator (4), (5), (6), and (7) represent 'teamwork and leadership skills'. In this current global economy, it is essential to "collaborate productively in large interdisciplinary teams" (American Institute of Graphic Arts, 2015), and these two skills are highly important for the GD graduates to interact successfully with others. Similar to previous studies on identification of the needed skill set for designers in general (Ramneek, 2017) and product designers in specific (Morrison et al., 2014), the findings of this study suggested that apart from fulfilling operational role, graphic designers may assume a more strategic or managerial role in contemporary and future design practice. D'Amico (2018) highlighted that teamwork is an important managerial skill required by future GD graduates, and that the ability to communicate clearly and interact effectively with other team members of the company and with relevant project stakeholders to satisfy the needs and demands of

clients from a wide variety of industries is as crucial as having an outstanding technical production capability.

Implications of the study

Both theoretical and practical implications were drawn based on the results emanated from the study. Theoretically, the present study has yielded a valid and reliable preliminary scale to measure the competency levels of new entrants to GD profession by conducting empirical analysis using survey data collected from existing final year GD degree students who study at HEIs in Malaysia. This scale is valid and reliable for GD related programmes providers at university level in Malaysia to investigate the mastery levels of the five major CDs of their graduates. In addition, interesting underlying factor structures for CCD, FCD, PCD, ECD, and MCD was discovered in this study based on the analysis of sample data. Such discovery is believed to have provided a new way of looking into the factor structures constituted of each CD for GD graduates. Further, studies on GD competencies did not disclose any previous initiative to consider the necessity of ethical related skills or knowledge for effective job performance. However, Cheetam and Chivers (1998:p.268) argued that that "no comprehensive [competency] model would be complete without an ethical component". The study contributed meaningfully to the literature through the inclusion of ethical dimension in the preliminary scale for measuring GD graduates' competency levels. Practically, though the developed measurement scale is preliminary in nature, it has many implications for GD education that are important for HEIs, design educators, policy makers, and students. The development of this scale is also crucial to the professional practice of GD in Malaysia.

Limitations and recommendations

The first limitation is the data analysis techniques used in the study. EFA and reliability analysis were employed to evaluate the validity and reliability of the proposed competency scale. However, these statistical analysis techniques are insufficient to test the theoretical foundations of a measurement scale (Segars & Grover, 1993). In other words, a confirmatory factor analysis (CFA) should be conducted to further evaluate the psychometric properties of the scale before it can be finalized.

The second limitation is a response bias in questionnaire design. The online survey constituted of 113 items (including demographic questions) and 31 pages. It was found out that the participants spent approximately 16 minutes on average to complete the whole questionnaire. Undeniably, some participants might not be able to sustain their focus until the end and therefore causing careless or random responses. In addition, this study used self-reported questionnaire, which might also lead to bias that could distort the obtained results (Karpen, 2018; Kountur, 2016). The study was unable to ensure that all participants would examine their knowledge and skills truthfully and to detect if they managed to estimate their abilities accurately. Therefore, there was a possibility that the collected responses might be inconsistent with the participants' actual competency levels. Accordingly, several recommendations were provided. The study focused only on reaching final year GD degree students who specialise in visual communication design, advertising design, digital and interactive design. However, Bridges (2016) pointed out there is a growing number of GD programmes concentrating on different media directions and levels, and this phenomenon has created 'confusions' in terms of what and how GD should be taught. As such, future replication studies may include students who major in different media directions or levels of study to enrich and strengthen the findings.

Currently, the developed scale could be used as a preliminary assessment tool to measure the competency levels of GD graduates. However, to further explore the construct validity of the questionnaire, an important next step will be to conduct CFA on item inter-correlations. This exercise is essential because, without further investigation, it will not be possible to enhance the accuracy and reduce the possible error of the scale. Further, it is encouraged to extend this study by exploring additional underlying factors under each CD. Such attempts are necessary to increase the precision level of the assessment and improve the theoretical foundation of the measurement scale.

Knowledge and skills companies seek from designers might be affected by different national contexts. Besides, the competencies that a GD graduate must possess is always under refinement as the technology and consumer culture continue to progress. This means, it will be necessary to ongoingly retest and expand the findings of this study in other countries, and then observe how the competencies required by the graduates potentially changes in different national contexts over time. In addition, designers in different disciplines have different professional interests and contribute to companies in different ways (Buchanan, 2001). This suggests that future replication studies may also compare the required skill set of GD graduates to those in other disciplines of design. The goal of conducting related studies, as highlighted by Wang (2006:p.81), is to "impact the supply of well-educated workers, advance numerous careers, and provide students with high-quality education and potential for employment" in a world that is constantly changing.

Conclusion

Certainly, no single GD graduate is likely to possess all the employability attributes as identified by the study. Likewise, no employer expects a graduate to be fully prepared when entering the field. However, what do the employers really expect is a high degree of self-awareness. The graduates should understand how to leverage their strengths and improve their weaknesses to function more effectively in professional practice if they successfully get employed. In light of this, a valid and reliable scale is needed to accurately measure the competency levels of the graduates and provide them with meaningful information about their current strengths and weaknesses.

In conclusion, graphic designers around the world, including Malaysia, are trying hard to prove they deserve a "seat at the table" (AIGA et al., 2019:p.54). As compared to professionals of other disciplines, graphic designers are no exception to demonstrate and maintain a high standard of professional conduct, performance, and responsibility to society in their practices (International Council of Design (ico-D), 2020). In such a context, the required competencies for young practitioners should be evaluated and refined iteratively as the needs and demands of the professional practice are constantly changing. To achieve a satisfactory competency outcome, relevant stakeholders and front-liners such as HEIs, design educators, industry professionals, policy makers, workforce development bodies, and design associations should collaborate intensively and establish sustainable underlying strategies that provide the needed supports for GD graduates when they begin their professional careers. The study believes that the establishment of such strategies will ensure the consistent supply of qualified, matured, ethically-minded, and well-rounded young design practitioners to fulfil the demands of the practice in the future. Only then, GD profession in Malaysia will continue to grow, expand its sphere of influence, and ultimately gain the respect it deserves.

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Visibility and legibility of five-letter words in different experimental conditions

ABSTRACT

The length of a word depends on the number of characters that make it up. Since we are constantly confronted with words (information), a suitable typeface should be chosen to make reading comfortable and easy. The number of characters can affect how visible a word is and, more importantly, how quickly the word can be read and understood. For this reason, we conducted tests with five-letter words randomly displayed at the four positions on the screen. The study examined the minimum time required to recognize five-letter words. Five different typefaces (Calibri, Georgia, Swiss 721, Trebuchet, Verdana) were included in the study to determine which of the screen typefaces read the fastest. The Georgia typeface performed the best regardless of the other conditions. The time to read upper-case letters was much shorter than lower-case and sentence-case letters. For words presented in the upper positions of the screen, the recognition time was shorter than for the lower positions of the screen. Different combinations of variables showed that some were better suited for on-screen use.

KEY WORDS
Reading time, typography, usability testing, visual performance

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Introduction

Information presentation is important aspect in everyday life, especially in advertising. Since the whole society is consumption-oriented, studies about information development are important. Products can be offered through different channels, television, web, social media, printed adverts, etc. (Jian, 2022). All approaches have certain requirements and benefits which can contribute to higher sale. Since our way of living is fast and we do not want to bother ourselves with things that take too much of our time or effort, commercial presentation should be as short as possible. For this reason, study of basic communication elements (colour, contrast, shape, position, duration) is quite important. For the reasons given, studying use of typography and time we need to see, comprehend, and remember the presented information (words, sentences) is important (Hohenstein & Kliegl, 2014). Many times, our focus is somewhere else, and this is not good for advertisers, especially if we are in surrounding where different disturbing factors are present (Karim & Kojima, 2010; Luccion & Caporusso, 2010). One of those environments could be use of computer (browsing the web) or watching television (either use of tv screen, computer screen or tablet/mobile screen) (Jessen & Jørgensgaard Graakjær, 2013). Advertisers are trying to serve products and sell them with affecting our subconscious. Fast commercials (banners)

which appear and disappear on the computer screen while searching web should be made in a way to attract our attention or affect our subconscious in a couple of seconds (maybe even milliseconds). To achieve public's attention, typography, position of presentation on the screen and time interval should be carefully examined (Ali et al., 2013). Probably all of us experienced fast, flashing commercials during web search. Those commercials appear suddenly and are present for certain time or until we close them. More interesting for our research is commercials which appear and disappear from the screen. They should be made in the way to subconsciously attract our attention and stay in our memory. In this way we are potential buyer/user of certain product or service (Aidin, Hamolton & Rohm, 2020).

Since legibility represents the ease of single character detection and it is measured with the recognition speed, use of typography is one of the most important factors (Arditi & Cho, 2005). Certain properties of typefaces can be advantageous for fast presentation and consequently perception (Cosky, 1976; Frase & Schwartz, 1979). It is known that typefaces which were designed for the screen should contain properties such as higher x-height, bigger counter form and clarity of shapes. But this cannot be the only reason for the word (sentence, slogan) to be recognized fast and correctly comprehend (Arditi & Cho, 2007).

Another important aspect is presentation position (screen) of the displayed content (Stevens & Grainger, 2003). When we use computer screen for search of information, our focus is mainly on the top positions of the screen. The data that gives vital information or attraction is normally positioned in the top left corner of the screen (Dhou, Hadzikadic & Faust, 2018). If we are performing fast search of information, the so-called Z pattern of eye movements is the fact. We start to read/search in the left top corner of the screen, followed by the glance to the opposite side, then we move across the screen obliquely to the left bottom position and continue to the right bottom position. In this way our attention is spread across the screen and is likely to perceive information we are looking for (Zhou, Helander & Jiao, 2011). Another pattern is also known for information search, so-called F pattern. This way of information search is maybe not so popular any more since layout of web pages has changed in the past years and the information of importance is not always placed to the left vertical position of the screen. Nevertheless, if people follow the Z or the F pattern, first or second move is across the upper part of the screen and is basically similar within both patterns.

When the advertisement is placed on the screen for unlimited time, the web user will have enough time to see the advert (if the advert is in her or his interest). In many cases while searching the web you are forced to shut down the advertisement with the (mouse) click.

This kind of situation is not really something that would be in the greatest interest of our research. This situation of course affects our subconscious but not in the way we are trying to outline the situation. More interesting are fast commercials that appear and disappear automatically. When they flash on the screen our attention immediately goes to them for short period of time. Sum of all elements that are presented in couple of seconds is the area that especially interests us (Bock, Monk & Hulme, 1993). If the elements are built properly, they will attract our attention more and will have higher effect on our subconscious. It is true that bad design can also attract our attention but will not convince us to buy certain product or use service. So, the important thing is to make a good design and harmoniously assemble all the basic elements (Dyson, 2004).

Another aspect which we must consider is the length of presented words. Since banners are offering different products, we focused on sport equipment (Manchanda et al., 2006; Teng et al., 2021). If we for example take the sports brands that are popular and spread all around the globe, we can measure average length (average number of letters consisting of them) as the measure of word length. Brands such as Adidas, Asics, Benger, Diadora, Fila, Head, Kappa, Lotto, Mizuno, Nike, Oakley, Peak, Puma, Reebok, Wilson consist of 4 to 7 letters and the average word length is 5.2 letters. This can be a measure for word length of presented words. All the presented words in the research were 5 letter meaningful words taken out of Slovene language dictionary and are in everyday use.

Method

Studies on readability are concerned with the isolation of words (Bouma, 1971). For this reason, we decided to conduct an experiment in a laboratory setting. The procedure for performing the experiment proceeded in the same way as used in the article by Pušnik, Možina & Podlesek (2016a). Since we wanted to find out how the shape of the letters, their size and position affect the recall of the words presented, the experiment was conducted in such a way that no other distractions were present (Carlson, Hogendoorn & Verstraten, 2006; Carrasco, Giordano & McElfee, 2004). The environment of the laboratory was painted in grey colour so that there was no (or very little) amount of reflection; the walls of the laboratory were painted in grey colour according to the standard ISO 3664:2009 (E) (International Organization for Standardization, 2009). The reflectance of the monitor was in accordance with the standard ISO 9241-307:2008 (International Organization for Standardization, 2008) and was higher compared to the environment.

Since we were interested in how letter (word) shapes affect recognition and retrieval of presented words, we

decided to run tests with very short presentation times, measured in milliseconds (Sheedy et al., 2005). For this reason, we prepared a web application to automatically determine typeface and position. The pool of 200 words was prepared for each trial (lower-, sentence-, upper-case) and words were selected randomly without replacement; the position of the displayed word was also randomly determined. The typeface sizes were adjusted so that each word displayed took up approximately the same area (square) in terms of size (horizontally and vertically) (Treurniet, 1980; Pušnik, Podlesek & Možina, 2016b; Ohnishi & Oda, 2021). For this purpose, we used typeface sizes as listed in Table 1. Given these sizes, the typefaces displayed were the same size, so it was not possible to prefer any of the five typefaces (Moret-Tatay & Perea, 2011; Nazir, Jacobs & O'Regan, 1998).

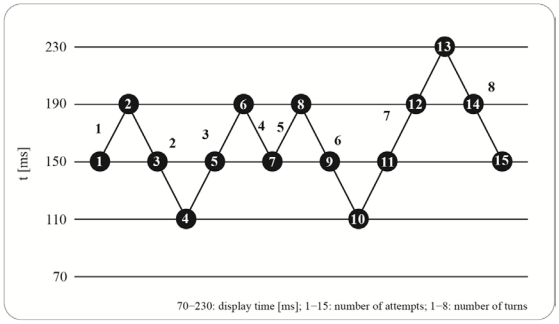
Table 1

Typeface size adjustments

Typeface	Size in points (pt)	Size in pixels (px)
Calibri bold	36	48
Trebuchet bold	33	44
Swiss 721 bold	32	42
Verdana bold	32	42
Georgia bold	33	44

The length of the first stimulus in the experiment was set to 150 milliseconds. After that, the presented word had to be typed into the field. If the presented word was typed in correctly, the next presentation interval shortened by 40 milliseconds and the new word was presented in a time interval of 110 milliseconds (the presentation duration increased by 40 milliseconds to 190 milliseconds if the word was not typed correctly or not typed at all). According of this dynamic, we wanted to achieve 8 turns and thus complete the experiment. Because the words were displayed in a very short time, participants needed several attempts to complete the experiment. Ideally, the experiment was completed in 15 attempts, but this was mostly not the case. Figure 1 is attached for a better understanding of the procedure.

In the procedure described above, we measured the recognition threshold of the displayed words under different experimental conditions (typeface, letter case, position). By using short display durations, we can determine how typeface, letter case, and position affect the visibility and recognition of the displayed words. The latter were displayed in black colour (Hex #000000; RGB (0, 0, 0)) on a light grey (Hex #cccccc; RGB (204, 204, 204)) background of the LCD screen. The white colour space of the screen was set to D65 and the luminance of the screen was between 80 and 160 cd/m².



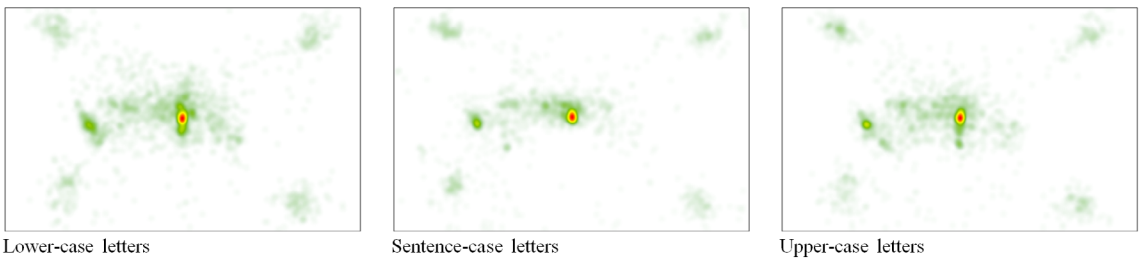
» **Figure 1:** *Web application operation*

Measurements were divided into three sessions based on letter cases: lower-, sentence-, and upper-case letters (see Table 2). Before each session, the procedure was explained to the participants, and they were able to get accustomed to the laboratory lighting conditions during this time. In addition, the instructions were displayed on the screen (in writing) before the start of each experiment.

The study included 30 participants for each of the three sessions. Their ages ranged from 20 to 30 years (M = 22.7 years). Since sports brands are popular among people between 20 and 30 years of age, we believe that the selected focus group was suitable for the experiment.

During the test, we also use an eye movement tracking device (TOBII X120) that allows us to monitor whether participants are following instructions and to evaluate the results obtained as objective (Rayner, Slattery & Belanger, 2010). Figure 2 shows the heatmaps illustrating the participants' eye movements for each set of words (lower-, sentence-, upper-case) displayed.

It can be seen from the Figure 2, that participants followed the instructions. We notice that the greatest concentration of views (heatmaps) is in the central part



» **Figure 2:** *Heatmaps obtained with eye tracking device*

of the screen, as it represented the starting point for each trial. The fixation point was positioned at the height of the observer's eyes. The distance from the center of the screen to one of the four corners of the screen (upper-left, upper-right, lower-left, lower-right) where words were presented was in this case the same and it could not happen that the display of a word in a certain position could affect its better visibility and faster perception. In addition to the center, we see a greater concentration of views also to the left of the center; here was the place where the participants typed in the words shown.

Results and discussion

The hypotheses of the experiment were tested with an alpha error rate of 5%. Table 2 shows the recognition thresholds for five-letter words (i.e., the shortest times required to correctly recognize five-letter words) presented under different experimental conditions.

Using the data collected in Table 2, we can see that five-letter words were recognized correctly faster when they were presented in the upper part of the screen (i.e., the upper left and right parts of the screen). When comparing the average recognition time for the upper positions, we can see a small difference (the difference between the upper left and upper right positions was 0.5 ms, regardless of the typeface and its style). On the other hand, the average presentation time for word recognition when presented in the lower parts of the screen was almost 10 ms longer than when presented in the upper parts of the screen. When we compare upper-case and lower-case words, we find (Table 2) that the recognition time is shortest for upper-case words (it varies between 140.0 and 152.6 ms). On average, the recognition time for upper-case letters was 146.9 ms (regardless of position and typeface). On the other hand, the recognition time for sentence- (158.4) and lower-case (159.5) letters was on average between 11.5 and 12.6 ms longer (as before, independent of position and typeface).

Focusing on the presented typefaces, we see that Georgia was recognized the fastest, regardless of the letter-case (lower-case, upper-case or sentence-case) and position (upper and lower position). In second place (with the shortest recognition times) was Trebuchet when presented in sentence- and upper-case. Verdana typeface stands out when presented in lower-case. Position is exempt (similar as for Georgia) when comparing letter cases for Trebuchet and Verdana. Recognition times for words presented in Calibri typeface are not much longer compared to those for Trebuchet (lower- and sentence-case), but they are when Calibri is presented in upper-case. Among all conditions, the Swiss721 typeface has the longest recognition times and, according to the collected data, is the least suitable for fast recognition when presented on the screen.

The results of ANOVA, presented in Table 3, show that there is a statistically significant main effect of all three factors tested: letter case, position, and typeface. Since there is statistical significance, we can assume that there is a significant main effect on the recognition threshold. When comparing the combination of different factors (Table 3), we notice that there is no statistically significant interaction between them.

It was expected that performance would be best for upper-case letters, followed by sentence-case letters,

Table 2

Average recognition thresholds in milliseconds (and standard deviations in parentheses) needed for recognizing words in different experimental conditions

		Position				
Letter case	**Typeface**	**Upper left**	**Upper right**	**Lower right**	**Lower left**	**Total**
Lower	Calibri	157.7 (16.1)	154.2 (25.4)	163.7 (13.3)	158.7 (17.9)	158.6 (18.2)
	Trebuchet	154.7 (17.8)	156.5 (20.6)	165.7 (12.4)	162.5 (19.2)	159.9 (17.5)
	Swiss 721	162.0 (16.5)	161.0 (18.7)	165.3 (12.1)	166.7 (20.8)	163.8 (17.0)
	Verdana	157.8 (22.6)	155.5 (24.2)	162.7 (13.4)	158.0 (19.8)	158.5 (20.0)
	Georgia	150.8 (19.7)	153.8 (25.6)	161.2 (16.7)	161.5 (17.2)	156.8 (19.8)
Sentence	Calibri	152.2 (26.9)	154.7 (30.6)	160.8 (19.5)	162.3 (15.3)	157.5 (23.1)
	Trebuchet	151.0 (26.5)	154.2 (27.4)	160.7 (14.0)	163.2 (16.3)	157.3 (21.1)
	Swiss 721	157.2 (22.6)	163.8 (22.2)	164.7 (9.1)	168.7 (15.5)	163.6 (17.4)
	Verdana	154.3 (20.1)	159.2 (28.0)	159.7 (12.9)	164.7 (15.9)	159.5 (19.2)
	Georgia	148.8 (24.3)	147.7 (33.8)	160.2 (11.3)	160.5 (18.9)	154.3 (22.1)
Upper	Calibri	142.0 (25.4)	145.3 (26.1)	152.8 (17.4)	153.5 (18.8)	148.4 (21.9)
	Trebuchet	143.7 (23.7)	137.0 (33.5)	152.5 (17.6)	154.0 (18.9)	146.8 (23.4)
	Swiss 721	150.7 (24.2)	145.0 (27.3)	157.3 (13.8)	157.3 (17.3)	152.6 (20.7)
	Verdana	141.3 (24.9)	144.7 (26.7)	154.0 (15.1)	147.5 (21.1)	146.9 (22.0)
	Georgia	136.8 (28.6)	136.0 (30.7)	143.8 (19.3)	143.5 (25.5)	140.0 (26.0)
Total	Total	150.7 (22.7)	151.2 (26.7)	159.0 (14.5)	158.8 (18.6)	

Table 3

Results of ANOVA of recognition thresholds.

Source of variability	SS	df	MS	*F*	*p*	η_p^2	Results of post hoc comparison
LC	58,066.75	1.86	31196.47	31.17	.000	.52	Upper < Sentence, Lower
Error (LC)	54,018.25	53.98	1000.74				
P	28,384.50	1.96	14508.95	5.19	.009	.15	Upper left, Upper right < Lower left, Lower right
Error (P)	158,548.83	56.73	2794.60				
T	16,613.69	3.14	5286.31	20.89	.000	.42	Georgia < Trebuchet, Calibri, Verdana < Swiss 721
Error (T)	23,067.14	91.14	253.09				
LC × P	2605.25	4.01	649.10	1.26	.290	.04	
Error (LC × P)	59,936.42	116.40	514.94				
LC × T	2087.14	5.29	394.73	1.71	.133	.06	
Error (LC × T)	35,494.53	153.34	231.48				
P × T	1843.97	7.77	237.42	0.74	.649	.03	
Error (P × T)	71,918.53	225.23	319.31				
LC × P × T	3955.86	11.74	336.94	0.89	.559	.03	
Error (LC × P × T)	129,319.14	340.48	379.82				

and that performance would be worst for lower-case letters (longest recognition thresholds). The results confirmed our conjecture, but with small differences. Upper-case letters were processed the fastest, but there was no significant difference in processing times for lower-case and sentence-case letters.

To find the reason why lower-case and sentence-case letters were processed (recognized) more slowly, we performed a typographic tone value (TTV) measurement (Table 4). TTV is defined as the relative amount of ink per square inch, centimeter, or pica.

Table 4

Average TTV* (%) of presented words

	Upper case	Lower case	Sentence case
Calibri	20.3	15.7	15.8
Trebuchet	23.3	18.2	18.3
Swiss 721	27.5	21.1	21.2
Verdana	28.1	24.1	25.0
Georgia	21.4	19.1	19.3
Average	24.1	19.6	19.9

**Typographic Tonal Value*

Upper-case letters stand out with the highest average TTV of 24.1%. The TTV for lower-case and sentence-case letters is much lower than that for upper-case letters; on average, the TTV for lower-case letters was 19.6% and for sentence-case letters 19.9%. %. In average TTV for lower- and sentence-case letters was smaller for between 4.2-4.5%. We can still see that sentence-case letters have a slightly higher TTV compared to lower-case letters. The reason for this is the use of a capital letter in each word. Nevertheless, the average percentage for sentence-case letters is still much smaller compared to upper-case letters. The difference in TTV may also be one of the reasons that the recognition threshold (processing times) for words is longer when they are presented in lower-case or upper-case. The highest TTV leads to shorter processing times (recognition threshold), while a lower TTV consequently leads to longer processing times (recognition thresholds).

The analysis of the positions shows that there is a statistical significance when comparing the upper and lower positions on the screen (Table 2). Namely, when the words were presented in the upper positions of the screen, the recognition times are shorter and comparable for the left and right positions (Table 2). A similar observation occurs when comparing recognition times for the lower positions on the screen. Regardless of the lower left or right position, the recognition times were longer than those for the upper left and right positions (Table 2). As it turns out, we have internalized the way we search for information online or on a cell phone. All-important data is usually displayed at the top of the screen when browsing web pages (regardless of screen size). We can assume that this is the reason why participants were more inclined to see the information in the upper part of the screen than in the lower part of the screen. Banners that appear and disappear on the screen are in many cases placed in the upper part of the screen.

The comparison of the typefaces shows that the shortest recognition times are achieved with Georgia, regardless of upper- and lower-case and the position of the letters (Table 2). The longest recognition times are achieved with the typeface Swiss721 (independent of upper- and lower-case and position). For the other typefaces (Calibri, Trebuchet, Verdana), the recognition times vary. From this we can conclude that it is more difficult to highlight the differences between linear typefaces when measuring and evaluating their usefulness in cases where words appear and disappear quickly. It is perhaps somewhat unusual that Verdana does not stand out among

the linear typefaces tested, as it is known for its open strokes, strong lines, and larger counter shapes (white).

The results from ANOVA of the recognition thresholds confirm our result based on the average recognition times (Table 3). If we must rank the usability of the typefaces, we can see that the Georgia proved to be the best, followed by Calibri, Trebuchet and Verdana, and the last one is Swiss 721. Despite the general opinion that typefaces belonging to the group of linear typefaces are better for screen display, our experiment showed the opposite. It looks like the serifs, which are part of the Georgia typeface, helped to better perceive the spacing between adjacent letters. Another reason why the Georgia typeface stands out from others is due to the stroke width or the difference in stroke width that is present in the Georgia typeface. Letters with serifs tend to have slightly larger spacing between letters, which can prove helpful for readers/users when reading short words (assuming that five-letter words can still be considered as short words).

Conclusion

Study of five-letter words shows how letter case, typeface, and position on the screen are affecting word recognition which is consequence of processing speed. Based on obtained results, the recommendation for displaying short inscriptions (company names, slogans, other promotional expressions) to be presented on the screen would be to place the words at the upper positions (left or right) on the screen. As for the properties that should be used for such titles, we recommend using upper-case letters and typefaces with distinct design features such as difference in stroke thickness, inclusion of serifs, greater counter-form, etc.

Based on recent research it would be advisable to use typefaces with a higher typographic tonal value (TTV); in our case tested typefaces were all presented in bold style which have higher TTV compared to regular, medium, or other styles. It would be maybe interesting to make comparison between bold and extra bold style.

Recent experiment included only five-letter words. We assume that participants who participated in experiment subconsciously used peripheral vision to obtain presented five-letter words. Since word presentation was given in milliseconds, there is a small chance that the participants were able to catch and see the displayed words with their eyes. Based on this we assume that there was little or no cases when participants directed their gaze to the stimuli.

Based on research performed by Ito (2012), saccades to an unexpected stimulus normally take around 200 ms to be triggered and then typically last about 20-30 ms during reading. In our case the average recognition threshold was less than 160 ms (more precisely 154.9 ms). Similar research, performed by Pušnik, Možina & Podlesek (2016a) where three-letter words were presented shows that in that case average recognition threshold was also less then 160 ms (more precisely 155.9 ms). We can see that average recognition threshold for five-letter words compared to three-letter words is 1 ms shorter. Perhaps we can justify this with greater surface coverage and greater typographic tonal value; both are higher with longer words (words consisting of more letters).

When different ads appear on the screen, addressing us with the help of words, they are displayed for a longer time, measured in seconds and not milliseconds. Due to the longer display time, users also have more options to direct their gaze to the displayed caption, view it and bring it to the level of recognition. Nevertheless, due to the fast display, we can conclude about the properties that are useful for the fact that the captions are processed and brought to the level of recognition in the shortest possible time.

Surface coverage seems to play a crucial role in the fast perception of words. In the future, it would be good to find out what the minimum surface coverage is when we are still perceiving words and what it is when we are unable to recognize words (or have difficulties to see and remember them). In addition, it would be interesting to see how different colour combinations between the background and the typeface used can help to process words faster, e.g., brands, slogans, and other written advertising material.

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