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EVALUATING A VISUAL TOOL FOR SYSTEMATIC DATA COLLECTION AND ANALYSIS FOR DESIGN STUDENTS

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ABSTRACT

In creating a successful product it is important to understand consumers' perceptions of a product early in the design process. Often, design students lack the necessary data collection and user testing skills to support effective design decision-making. Consequently, their products might not be acceptable to the intended consumers and are thus likely to fail in the marketplace. For design students to acquire those skills, design curricula should incorporate statistical courses teaching the concepts of data and user testing. We addressed this challenge by developing an automated tool named DACADE, assisting design students to systematically collect and analyze data. This paper reports the user acceptance study of DACADE designed to determine its level of user satisfaction and aesthetic appeal. The results confirmed a need for a formal introduction to systematic sampling, collection of performance data as well as of opinion data, data analysis, interpretation, and application of statistics to product design.

Keywords: user experience, user acceptance, user satisfaction, design students, visual techniques, consumers' perceptions, product design.

INTRODUCTION

When developing product ideas, designers tend to rely on intuition or experience. For example, experienced designers engage in sketching and drawing while interacting with clients in order to reach to the best product design solution [1-3]. Although this may be useful for experienced designers, there are limits to how far the idea of sketching and drawing can be used to gather data, especially for novices who may lack the skills and experience to communicate effectively with consumers. Further, the process of sketching and drawing is insufficient as a basis for sound decisions with no input from consumers. Additionally, some designers rely on their intuitive understanding of user needs and preferences based on everyday activities and exchanging ideas among themselves with no involvement of users to inform design-related decisions [4-7]. Creators of design curricula have tended to disregard courses that incorporate user preferences, views and needs that enable a design student to involve consumers in the product design process [4].

Design students are taught to believe in their own intuition and creativity [8], which is fine, except that they also need to verify with their target audience that their ideas are acceptable. Consequently, designers often rely heavily on personal preferences, tending to understand the term "research" as the gathering of archival information instead of running user tests to inform design decisions [9, 10, 5].

Nevertheless, neither intuition nor experience suffices in the growing trend towards mass production to produce successful products, as highlighted by Norman [11].

"Design needs to develop its own experimental methods. They should be simple and quick, looking for large phenomena and conditions that are 'good enough'. But they must still be sensitive to statistical variability and experimental biases. These methods do not exist: we need some sympathetic statisticians to work with designers to develop these new, appropriate methods" p.4 [11].

According to Norman, traditional design activities must be supplemented by an understanding of technology, business and human psychology. In addition to shortening development cycles, products now need to provide greater emotional satisfaction as well as excellent functionality. Understanding and identifying consumers' needs in the early stages of the product development process are important to create successful products [12]. Frascara and Noël [6] suggested that design must be "user-centered, evidence-based and result-oriented". They emphasized "…we need to develop and teach appropriate conceptual and practical tools, and educate students in those tools so that human needs and wishes and even emotional, cultural, cognitive or other flaws can be addressed" p.4.

Increasingly, to be successful, designers must be able to provide valid empirical evidence to convince clients to invest in new products. Hence the need for acquiring skills such as the application of statistical methods is important.

In our preliminary study, 20 design students and 10 design lecturers were interviewed at one design institution. In addition, an email survey and archival research were conducted involving 51 universities that offer design courses in Australia, North America, Europe and Asia. The results suggested that none of the design lecturers teach statistics and none of the design students had learned statistics. The data showed that both design students and lecturers were only superficially familiar with some qualitative data collection methods but not with quantitative methods. This lack of familiarity extended to the very notion of quantitative data. Neither design students nor lecturers in the sample knew of any

inferential statistical methods such as Analysis Of Variance (ANOVA) or Factor Analysis.

Our early investigations also suggested that design students might benefit from a visual and interactive method such as a visual software tool to assist them collecting and manipulating data. This insight was based on the responses given by the design lecturers during the interviews. These suggested that design students might benefit from a visual and interactive method such as a software tool to assist them in collecting and manipulating data. Design students also claimed that they are visually literate and prefer visuals to numeric information. These findings appear similar to Goodman, Clarke, Langdon & Clarkson's proposal that a design tool should be visual, interactive, concise and relevant to a design context [13]. Based on this feedback, existing visual tools that could potentially be suitable for design students to conduct systematic research were investigated. This sample included Computer Aided Kansei Engineering (CAKE) [14], Visual Research Package [15], Web 2D Analytical tool [16], and other automated visual tools [17, 18]. However, none of these tools addressed the lack of systematic data collection and analysis knowledge and skills among design students, and nor did they encourage design students to use statistics in the early phases of design projects, suggesting the need to design a new tool with appropriate methods for that audience.

Designing a new tool: DACADE
Data collection and analyses techniques

In DACADE, two techniques were used for data collection: Blank screen and 2D map. One allows evaluators to position product images on a blank screen in any way they like. Products positioned close to another are perceived to be similar; those positioned far apart are seen to be different. Once all images have been placed, evaluators are asked to enter adjectives that meaningfully represent the products/groupings. Based on the first sample of evaluators' selected terms, the technique then enables designers to select suitable pair of adjectives for further study. This technique is widely used in the food industry for sensory analyses [19]. The second technique, a 2D map can be applied to evaluate products for which designers have already selected sets of adjectives or Semantic Differential (SD) scales [20], for example, from the literature. The 2D map technique allows respondents to drag-and-drop pictures or stimuli on a 2-dimensional space based on the sets of adjectives provided on the map. The 2-dimensional space is an intersection of X and Y coordinates forming four quadrangles, with negative adjectives at the bottom and on the left side and positive adjectives at the top and on the right side. This technique allows the designer to generate a perceptual map based on test users' perceptions. Elaborating further, perceptual maps are popular in marketing for studying consumers' product perceptions. Products include consumer products (e.g. toothpaste, cars), industrial products (e.g. computers, tools), institutions (corporations, hospitals, universities), activities (vacation spots, movies) or people (entertainers,

political candidates) [21]. This second technique of collecting data is used in DACADE because it is easy to interpret, and it provides visual output, consistent with designers' preference for visual rather than alphanumeric information [22]. For data analysis, DACADE used basic descriptive statistics such as the mean, the median and the mode as well as frequency to introduce design students to the basics of descriptive statistics. In addition, DACADE also used Multidimensional Scaling (MDS) [23, 24] assumption-free nonparametric Guttman-Lingoes Series that rely on visual and spatial information to generate a perceptual map.

After selecting these two data collection and analysis techniques deemed suitable for design students, the interactive tool design process continued with the design and evaluation of the DACADE prototypes.

Usability tests

Two formative usability tests were carried out to evaluate the early DACADE prototypes [25]. A separate prototype was produced for each of four tasks, namely (1) designing a new study, (2) editing an existing study, (3) collecting data (i.e. running the study) using both abovementioned techniques, and (4) conducting simple descriptive statistical analyses. The analysis component calculates the median, mode, and mean of the research data as well as providing a visual output of the distribution of objects tested. The prototypes were evaluated iteratively with a sample of eleven design students at one design institution in the formative usability tests to satisfy the pre-determined usability goals. Written task instructions and relevant task scenarios were given. Task requirements were generated separately for each task and given to participants one at a time. All tasks were completed in the same order (1-4).

The first test revealed several usability issues as well as generating valuable comments that were incorporated into the revised DACADE prototype before re-submitting it to the second test. The first test also revealed serious misunderstandings of simple descriptive statistics, which necessitated the addition of a tutorial to DACADE covering all four components with exercises as a basic explanation and illustration of descriptive statistics. The independent test of the tutorial prototype yielded no usability problems. Therefore, it was integrated into the revised DACADE prototype for the second usability test using the same tasks and method in usability test #1, except that the test users were asked also to work through the tutorial and complete the included exercises. Very few new usability issues were found; these were eliminated prior to implementing DACADE. Importantly, the test demonstrated that the students were still unable to grasp the basic concepts involved in data collection, analysis, and interpretation. Consequently, we had to limit the descriptive statistics to include only frequency counts and the mean, removing the median, the mode, and the MDS analysis to avoid misunderstanding, at least for a start. It was decided that more statistical concepts could be added later in future enhancements of DACADE.

Look and feel

The look and feel of the DACADE user interface was decided upon just prior to implementation, because it was impossible to do with the paper prototypes. The main objective of those was to focus on the usability issues and not on the aesthetic issues such as background colour, font size or font colours. At that point it was decided to apply a Mac-friendly design interface that would also comply with the accessibility standards for the World Wide Web [26]. However, when discussing the possible platforms, the software developers informed the researcher they would focus only on a desktop version in the first instance for the sake of simplicity and in the interest of saving time and money. They added that, the web browser could still be viewed on a tablet device, such as an iPad.

With respect to screen orientation, it was decided to use landscape instead of portrait for a better view of the image-positioning task.

The DACADE color palette was also decided at the time of the software implementation. In consultation with designers in the School of Design, several color palettes had been assessed. An online Google survey directed at designers was then distributed via Facebook and email communication. The targeted respondents were 18 years or older. Participants were asked to rate three different interfaces, all similar in layout but with different colour palettes. Interface #1 had a white background, interface #2 had a 5% Grey background colour, and interface #3 had a darker grey background colour. Ratings were made on a scale ranging from 1 ("not pleasant at all") to 10 ("extremely pleasant"). A total of 24 advanced graduate design students volunteered to complete the survey. Interface #2 yielded the highest mean rating (M = 6.96, SD = 1.94) as opposed to interfaces #1 (M = 6.83, SD = 1.90) and #3 (M= 4.58, SD = 2.28). A One-Way ANOVA was conducted to compare the two means and the results indicated a significant difference. Interface #2 was therefore selected for DACADE and handed to the software developers for implementation.

It is important to note that despite the DACADE prototypes having been thoroughly tested in the formative stages and found to fulfill the pre-determined usability goals, the software developers independently made several changes to the design of certain buttons, actions, and navigation paths for technical reasons, time, and cost.

After implementation, the User Acceptance Study presented here was conducted to (a) determine the degree of acceptance of DACADE among design students, and (b) assess its perceived appropriateness to that audience before releasing it for more widespread use.

METHOD

Participants

Thirteen undergraduate and graduate design students (5 female, all 18-40 years of age) representing various areas of design (Communication Design, Industrial Design, Interior Design and Film & Television) from one institution took part in the study. It is important to note that the small participant pool was justified by the fact that no new problems arose during the test [27]. Participants were tested in individual sessions taking between 30-60 minutes each, and they were given a voucher to the value of $20 upon completion of the test.

Materials and design

Instructions to participants, the informed consent form, consent information statement and a demographic information form were prepared. The University ethics committee granted ethics clearance. All sessions were audio recorded with permission and transcribed verbatim.

Task scenarios and cover stories similar to the previous usability tests [25] were used for each task and for each of the two analysis-types; Blank Screen or 2D map. It should be noted that the Blank Screen technique was chosen because it is spontaneous, flexible and able to inform a list of consumer-identified adjectives, and it can be used as a 2D map technique as well. A 2D map is a visual technique ideal for design students as it allows direct or automated data entry into a software tool in which it can be analyzed immediately. Potential human error in the data entry process can thus be avoided.

Tasks were given to participants, one at a time. Each participant received one set of 4 tasks, using either the 2D map (participants, n = 7) or the blank screen technique (n = 6). The presentation of these was counterbalanced to avoid serial order effects.

The DACADE tutorial contained three exercises in addition to an introduction to, and explanation of, four sections included in the tool, namely (1) create a new study, (2) edit an existing study, (3) analyse data collected and (4) run a study. Both the two visual data collection techniques mentioned earlier were included, namely the 2D map and the blank screen. Figure-1 shows the 2D map that enables users to position products.
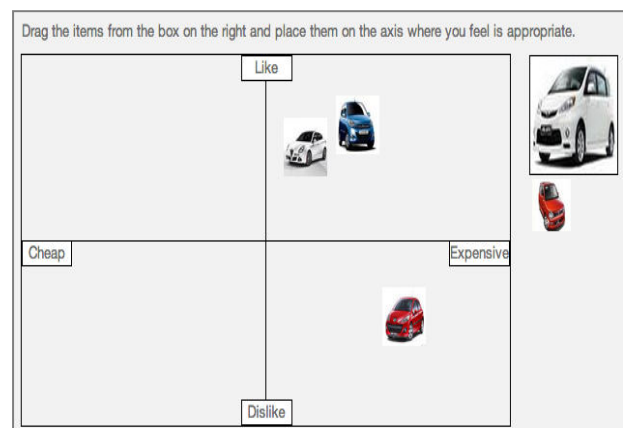

Figure-1. The 2D map technique used in DACADE.

Any object (or product) positioned on the left side is thus perceived to be worse than objects positioned on the right side, and objects positioned at the bottom are perceived to be worse than objects positioned on top of the map. Participants can position product images anywhere

on the map, based on their own judgment. DACADE then produces an overall map of all participants' product placements with visual statistical results. In the blank screen technique (see Figure-2) participants simply drag and drop the product images anywhere on the screen and label groups of images with adjectives they consider most suitable. With this technique, DACADE will then provide a complete list of user-generated adjectives for future research.
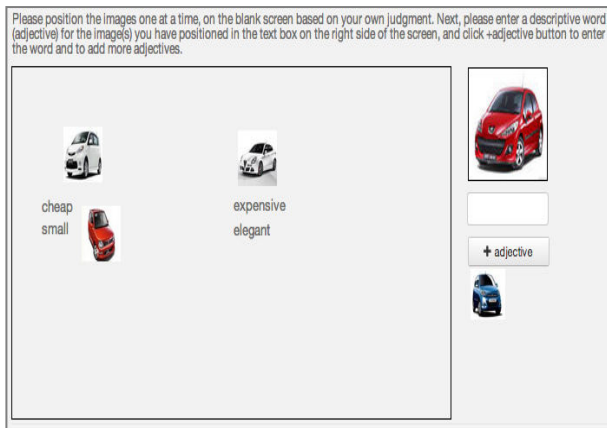

Figure-2. The blank screen technique.

In addition to the 2D map technique, DACADE also supports calculation of the mean (Figure-3) and the frequency of scores (Figure-4). These statistics were introduced because they describe the basic features (central tendencies) of the data, presented as a simple summary considered important and appropriate for design students, given their limited understanding of quantitative data and the purposes these serve. The explanation of the mean and frequency was illustrated using books measurement (height) based on the feedback gathered in usability test #2 [25].
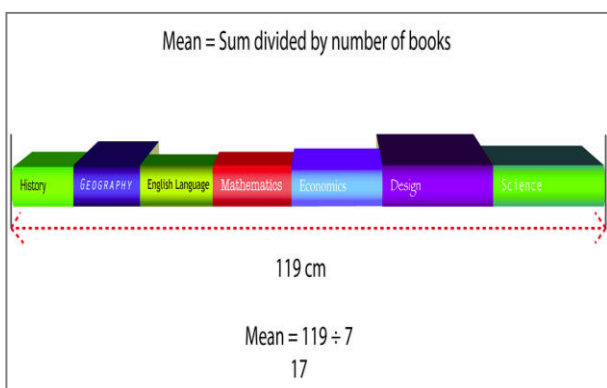

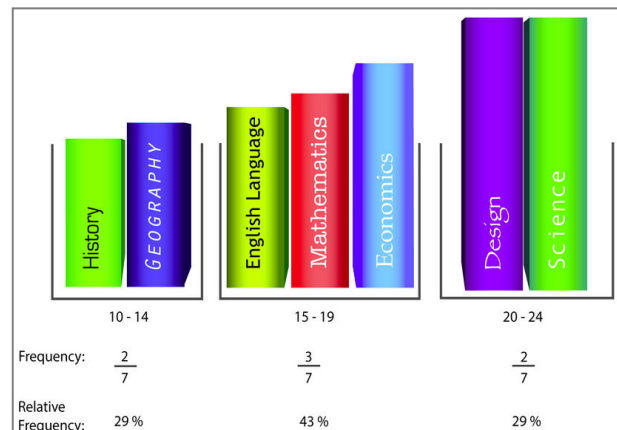**Figure-3**. Illustration of the mean.

Figure-4. Illustration of the frequency.

For the tool to be acceptable, the criteria for acceptance, perceived usability, satisfaction and visual aesthetics were set to an average of at least 70% each. Performance data were also checked for objective usability. Perceived usability and satisfaction were measured by the 5-point SUS scale [28]; aesthetics was measured by the VisAWI 7-point scale [29] and five additional questions sought participants' opinion about DACADE on a 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree).

Procedure

Upon arrival in the test lab, participants were welcomed and briefed about the test before reading and signing the informed consent form and filling in the demographic information form. Next, they worked through the tutorial, completing the exercises at their own pace before reading the relevant cover story and then attempting the four test tasks, one at a time. They were asked to verbalize their thoughts as they went. At the end, participants filled out the remaining scales and were invited to provide any additional feedback or asking any further questions. Finally, they were paid and excused.

RESULTS AND DISCUSSIONS

DACADE tutorial

Table-1 shows that performance was reasonable on all but exercise 2C asking them to select the most modern (traditional/modern) and boring (boring/interesting) product. It was surprising to note that no tutorial exercise yielded a 100% correct score. Only one participant managed to complete all tutorial exercises correctly but not without going back to the tutorial text when calculating the mean (as in Figure-3) as required in exercise #3 (see Figure-5). It is therefore not surprising that participants also experienced problems using DACADE.

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Table-1. Total number and percentage of correct answers to tutorial exercises across 13 participants.

Exercise	N correct (%)
1A) Selecting the best quadrangle	10 (76.92)
1B) Selecting the worst quadrangle	8 (61.54)
2A) Selecting the very best bottle	10 (76.92)
2B) Selecting the very worst bottle	8 (61.54)
2C) Selecting the most modern and boring bottle	7 (53.85)
2D) Selecting the most ambiguous bottle	8 (61.54)
3) Calculating the mean	10 (76.92)

Performance was better when identifying positive quadrangles (upper right half of the diagram, Exercise 1A) and products (Exercise 2A) than when asked to identify negative quadrangles (lower left half of the diagram, Exercise 1B) or products (Exercise 2B). One reason for the low score on exercise 2D might be a lack of familiarity with the word "ambiguous", as three participants asked about the meaning of it.

As shown in Table-1, ten participants completed exercise #3 correctly (see Figure-5), but five of these referred back to the tutorial to carry out the calculation for the dataset provided. One possibility for this is that they failed to attend sufficiently to the tutorial text to understand the concept of the mean clearly.

Figure-5. Exercise #3 for calculating the mean in the tutorial.

One participant confused the mean with the median by selecting the middle value from the list of dataset (see Figure-5); one made an arithmetic error summing the data, and one divided the sum by the number of values in the example provided in the tutorial text instead of referring to the question given in the exercise.

Overall, it took participants 20 minutes (SD = 11 min) on average to complete the tutorial including the exercises.

The tutorial performance results show that participants performed better on positive than on negative quadrangles, indicating that they needed more exposure, training and exercises on the concept of the 2D map, even of the simple concept of the "mean". Giving more exercises using descriptive statistics could also be of help.

It was clear that the target users could benefit from enhancements to DACADE such as providing more visual examples of mean calculations. The word "ambiguous" needs to be rephrased to "unclear" to avoid confusion among design students in future DACADE iterations.

Performance: Using DACADE

It is important to note that no new usability issues arose in the test. However, issues of consequence to the design of the tool were noted as presented in the four categories discussed next.

Groups and participants

Most of the problems occurring in the 'create a new study' task were related to the notion of participant-groups. Eight participants did not understand what these are, presumably, in part, because the possibility of contrasting and comparing the preferences of people belonging, for example, to different age groups or as a control for gender in a product test was not included in the test. Despite the relevant mouse-over tooltip, they were unable to identify the button allowing them to add groups. This misunderstanding of "groups" had also been observed in the formative usability studies [25].

The misconception of assigning a different number of participants to each group kept occurring despite the fact that all test participants had read the implemented tutorial. It is possible that the wording of the tooltip, "Click to add more groups", may have misled participants into believing that one group had already been created (see Figure-6).

Figure-6. The 'Add' button with a tooltip.

Frequency and mean

Seven of the 13 participants had problems obtaining the frequency of products in each quadrant in the 2D map technique. Five participants understood the concept but counted the frequency of the products manually instead of clicking on the relevant quadrant to obtain the visual frequency (see Figures-7 and Figure-8). The analysis menu screen actually presents instructions for obtaining the frequency, but five participants still had to be reminded to read it.
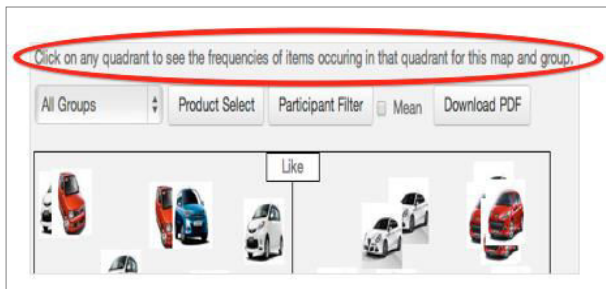
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Figure-7. The instruction for obtaining the frequency encircled in red.
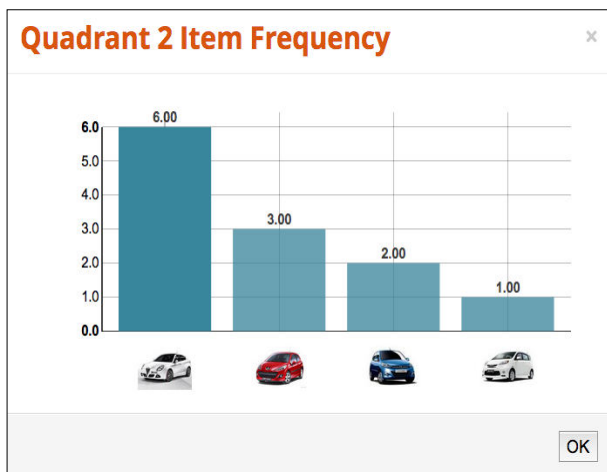

Figure-8. The frequency displayed upon selecting the option shown in Figure-7.

One possible solution could be to reverse the location of the instruction and the line of buttons (see Figure-7), following Western-world reading habits from the upper left to the lower right corner. Another two participants had forgotten what frequency means, needing additional help even though the concept had been introduced in the tutorial. Participants may have failed to pay close attention while going through the tutorial. An exercise for obtaining the Frequency could be added in future iterations to convey the concept better. However, this alone may not work as participants also had problems calculating the mean. Two participants calculated the mean manually by clicking on the quadrant instead of using the "Mean" checkbox button in the Analysis menu (see Figure-9) that would have given them the mean for all four quadrants. Despite both the tutorial and an exercise involving calculations of the mean, some participants still did not grasp the concept.

Another issue was that the mean was the only option with a checkbox placed in the same line as the three buttons (Figure-9). The row of options shown in the top line of Figure-9 contains one drop-down menu for changing the display of groups on the 2D map, three buttons (indicating Product Select; Participant Filter; and Download PDF), and the "Mean" checkbox.
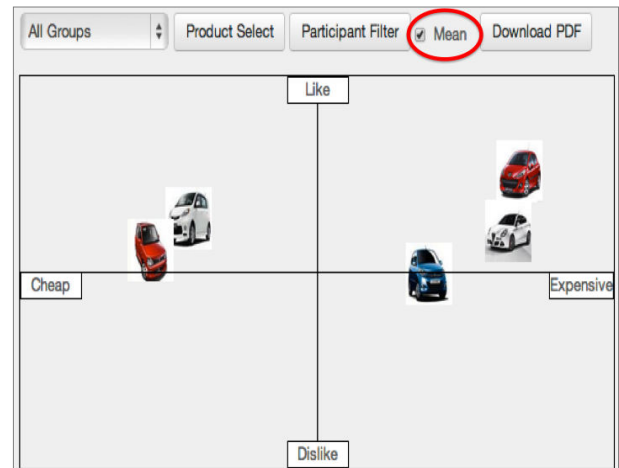

Figure-9. The visual mean on DACADE.

As illustrated, the mean is located in between the Participant Filter and the Download PDF buttons. This mixture of navigation tools was less than ideal and may potentially have been confusing. Participants took longer and needed guidance to find where to calculate the mean. One way to overcome that problem could be to place the "Mean" checkbox on the left side of 2D map instead. That way, buttons provided on this screen would be grouped together and aligned giving more consistency, whereby the mean as the checkbox button, on the left side can be seen clearly, hence less confusing. Additional experience using the tool should facilitate a better understanding of the purpose of the tool, in particular the statistical aspects.

Issues with the blank screen technique

All seven participants who used the blank screen technique needed guidance as well as reminders to read the instructions. The positioning tasks may have been a little unclear because the technique could not be tested properly on the paper prototypes. Entering adjectives perceived to be descriptive of product image clusters and positioning these was evidently problematic. Participants might have confused this action with the name of the "+adjective" button used (see Figure-10), or the instructions may have been too long (three sentences) (see Figure-11). This will be revised in future DACADE iterations. The button (+adjective) may need to be changed to a text box saying e.g. 'Type your adjectives here'. And the instructions may need to be rephrased into step-by-step instructions.
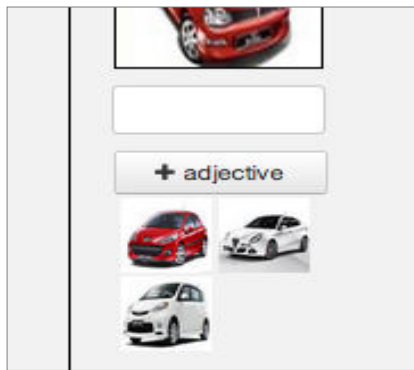
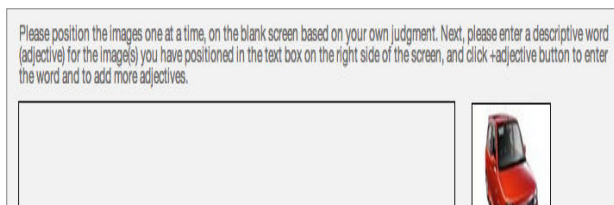**Figure-10.** The '+adjective' button on the blank screen technique.

Figure-11. The three sentence instructions for the blank screen technique.

Other issues

Other issues concerned participants being uncertain about what the tasks required them to do, needing a reminder to read the instructions or the task again, and apparently failing to attend closely to the relevant details on the screen. One participant refused to read the tasks, because she had spent a considerable amount of time on the tutorial (45 minutes against an average of 20 minutes). Additional minor issues related to the requirement of signing up or signing in; one participant did not realize that, as a new user, he had to sign up. Small mistakes also occurred such as forgetting to add another group, creating a new study instead of editing an existing study, or accidentally deleting wrong images. Some participants performed activities that were not in the task requirements. Most of these mistakes appeared to occur because of a failure to pay sufficient attention to details on the screen while performing the task. Allowing users more time to explore and familiarize themselves with the tool during training might be one way to avoid many of these minor issues.

Opinion data

The average score on the SUS in terms of perceived usability and satisfaction reached the preset criterion of an average of 70% (M = 73.85, SD = 17.37), suggesting that the tool was acceptable to the sample of users tested on those variables. The perceived Aesthetics scores on each of the four VisAWI facets also reached the 70% criterion as shown in Table-2.

Table-2. Average scores, standard deviations and percentages of the four facets on VisAWI for Aesthetics.

Aesthetics	Average (SD; %)
Simplicity	5.49 (1.44; 78.43)
Diversity	4.91 (1.43; 70.14)
Colorfulness	5.85 (1.27; 83.57)
Craftsmanship	5.86 (1.63; 83.71)

DACADE was thus perceived as being visually pleasing along all four aesthetics dimensions tested. Averages and Standard Deviations, as well as the Percentages associated with the additional questions concerning participants' opinion about DACADE are presented in Table-3.

Table-3. Averages, standard deviations and percentages of the participants' opinions of DACADE.

Questions	Average (SD; %)
Q1. DACADE is valuable to design students	6.23 (1.01; 89)
Q2. Interaction with DACADE is pleasant	5.69 (1.49; 81.29)
Q3. I would recommend DACADE to other design students	6.15 (1.68; 87.86)
Q4. DACADE inspired me to collect and analyse data in future design projects	6.23 (1.17; 89)
Q5. I would like to learn more about the power of statistics after using DACADE	5.85 (1.63; 83.57)

With three of the five questions reaching an average score exceeding 85.71% (6/7) and the remaining two questions 80% (5.7/7 = 81.43%) each, it is safe to conclude that DACADE was perceived to be valuable (Q1) and pleasant to use (Q2). The results also indicate that it would be useful for collecting and analyzing future data (Q4) as well as learning more about statistics (Q5). Participants also indicated that they would recommend DACADE to their colleagues (Q3).

Open-ended questions

Open-ended questions asked what participants liked the most, what they liked the least about DACADE, and suggestions for improvement were also invited.

The results showed clearly that many of the participants' difficulties understanding the purpose of collecting and analysing data from others in the product design phase as well as understanding the straight-forward calculation and interpretation of mean values. It is therefore somewhat surprising that ten of the 13 participants mentioned the data analysis function of DACADE as the most liked feature, even though this was also supported by the opinion data. It is, however,

encouraging that the participants seemed receptive to learning more about statistics, as also indicated by the responses to the opinion questions above. Another eight participants mentioned ease of use and five the colours among the most-liked features.

In terms of the features they liked the least, eight participants thought there was too much text, preferring a multimedia or video-based tutorial with more images and sound effects and little or no text. At the same time, four participants thought there was a "lack of instructions". Yet, as also shown above, many participants had to be reminded to read instructions when completing the tutorial tasks as well as during task performance as well as remembering to read information on the screen. This perceived "lack of instructions" was mostly referring to all images available in the DACADE tutorial. Participants did not realize that they could click on each image to enlarge and view larger image in a pop-up window in the tutorial. That instruction was provided in the tutorial and also given via a tooltip, but nearly all participants needed to be reminded that they could click on the images to enlarge it. Apparently, they did not realize that a tooltip was provided for every image. Changing a "click to enlarge" instruction from a tooltip (invisible) to the top of each image (visible) could probably solve this problem. That way, users can easily see the instruction without needing to point on each image to read the tooltip. However, adding text would also lead to unwanted screen clutter.

Participants wanted more guidance/explanations of some actions in the tool itself even though these are provided in the tutorial that all participants worked through prior to attempting the test tasks.

Several good suggestions for improvement were also made. One was to add further analyses in addition to the frequency and the mean. Given the problems participants had with the descriptive statistics provided, and the fact that calculations of the median and the mode had been removed upon observations and feedback from participants in the formative usability tests, this suggestion warrants a staged approach to teaching simple statistics. For example, one could call the present version the "introductory" DACADE and then provided an "advanced" version containing additional statistics once design students are comfortable with the issues currently provided. One participant recommended integrating this tool into one of their courses "…I would recommend if the unit required this type of research, many unit require you to research of existing design solutions…this is helpful for the design students, I think this a good system".

RECOMMENDATIONS

This study revealed that design students were hesitant to read. This was observed both with the tutorial presented in textual and graphical forms and with the formal tasks. Accordingly, this study proposed turning the DACADE tutorial into a "show and tell" video-based instructional resource with less text to encourage them to focus on the contents.

This study also suggests that design students find it difficult to understand why they should collect data from potential future users of their intended products. It would therefore be interesting to design a course dealing with these issues as well as teaching the fundamentals of statistical analyses, including simple analyses of parametric (t-tests, one-way ANOVAs, correlations) and nonparametric statistics (Mann-Whitney Tests, Wilcoxon Signed Ranks Tests, Chi Square). It may be possible to convey the concepts more successfully by providing students with more examples to which they can easily relate, such as buying a mobile phone. It is likely that design students have some experience selecting a mobile phone, for example, rather than selecting a new car. They would probably have compared different mobile phone plan deals, different service providers and different phones to ensure they select what best suits their needs. This simple example might help them to relate to data sampling from different sources in the process of making a good decision. Integrating this tool into the 'research methods' design course that covers sampling, data gathering and descriptive statistics can be a starting point.

It is notable that several participants had problems understanding the necessity for understanding the frequency of occurrence of participants' different opinions, and nor did they appear to grasp the importance of calculating the mean opinions in their own work. The same was true for the notion of participant-groups; some had problems realizing why they would need to assign an equal number of participants to each group. We proposed that additional examples demonstrating the merits of assigning people to different groups and comparing the performance and opinions of these might help. Additionally, more explanations and illustrative examples to convey these concepts more effectively should be added.

More training on the specific data-collection methods incorporated into DACADE (2D maps, Blank Screen techniques) can be provided to design students in order to gain familiarity with the tool.

DACADE is currently running only on desktop computers with MAC/Windows operating systems. Considering that most design students will eventually be working as practitioners in the field, it is also intended to expand DACADE such that it can be run on mobile platforms as well, and possibly also on other platforms.

Although DACADE was designed specifically to support design students testing their design ideas and prototypes, it would be interesting also to learn more about what experienced practitioner designers might need in terms of a tool such as this. At least some aspects of the tool would need to be redesigned for it to be acceptable to such an audience.

MAIN LESSONS LEARNED

Pay careful attention to the choice of words when conducting user tests with design students, and aim for simple and common words that are easier to understand and use in task-performance.

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In planning tests with design students, consider, carefully the length of instructions that participants need to read: be as concise and brief as at all possible to encourage them to undertake the tasks.

This study suggested that it would have been beneficial to involve the software developers from the very beginning as indeed recommended by User-Centered Design (UCD). Unfortunately, that was not possible here due to academically imposed time constraints. Therefore, the software developers were involved only during the implementation stage, once the predetermined level of usability had been reached.

Finally, and most importantly, researchers need to know the capabilities and limitations of the target audience from the outset. The researchers had assumed a minimal level of mathematical understanding that clearly was not present.

CONCLUSIONS

In concert with Norman and other researchers' statements about the lack of knowledge of empirical research among design students, it is safe to conclude that design students have very little knowledge about data collection and analysis, interpretation and application to design. This study confirmed that design students would benefit from a more formal introduction to sampling issues, the collection of opinion and performance data, data analysis, interpretation, and application of statistical analyses to understand customers' requirements in the design of products.

It is hoped that the successful development of DACADE as a visual tool to collect and analyse data efficiently for design students will spread its benefit in producing "evidence-based and results-oriented" products and most importantly, ultimately benefit the public.

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