INTERNATIONAL DESIGN CONFERENCE – DESIGN 2022
https://doi.org/10.1017/pds.2022.205

Biomaterials in Everyday Design: Understanding Perceptions of Designers and Non-Designers

N. A. A. Sayuti [1,2,✉], B. Sommer [2] and S. Ahmed-Kristensen [3]

[1] Universiti Teknologi MARA, Malaysia, [2] Royal College of Art, United Kingdom,
[3] University of Exeter Business School, United Kingdom

✉ aynsayuti@gmail.com

Abstract

The application of biological materials in everyday design is gaining traction and designers are encouraged to employ biological systems through biodesign and biophilia. However, there is a deficiency in the understanding of potential consumers' perceptions. This paper compares the perception of non-designers as well as designers towards design-embedded bio-materials. Data was collected from 234 respondents using an online survey. The findings were gathered by evaluating perception in terms of desirability, practicality, aesthetically, and familiarity with living and non-living biomaterials.

Keywords: perception, biomaterials, product design, industrial design, user experience

1. Introduction

Research investigating perception of products' function, aesthetic value, and emotional connection enable a better understand in user experiences; however, within the context of biomaterials is under explored, unknown or ambiguous, requiring further research (Sayuti et al., 2020 and Sayuti and Ahmed-Kristensen, 2020). The emergence of new trends in everyday product designs encouraging the embedding of biological materials in products – either directly or indirectly within the framework of bio-related design genre such as biophilic design, biodesign, bio-inspired design, biomimicry – is expected to lead to a growing usage of biological materials (Franklin and Till, 2018). Taking the usage of biological materials to the next level in product development with appropriate user scenarios and applications could motivate designers, scientists, engineers and relevant people to find solutions decreasing the negative global environmental impact of traditional materials. Furthermore, the inclusion of living biological components into structures, objects, and processes has expanded the usage of living biological elements beyond the scientific sector and into engineering and design (Myers, 2018). Examples are the Algae Lab and the Mycelium Project using 3D printing technology by Studio Klarenbeek & Dros – Designers of the Unusual, the Netherlands, Moss Table using ABS plastic, acrylic, carbon fibre, carbon paper with microparticles, neoprene, moss and soil by Carlos Peralta, Alex Driver and Paolo Bombelli, Local River by Mathieu Lehanneur (Myers, 2018) among other designs developed.

The availability of radical materials (Franklin and Till, 2018) represent another alternative approach (through biomaterials exploration) encouraging designers and scientists to investigate further in order to produce out-of-the-box everyday products design based on biodesign. The diversity created by the intersection of these diverse fields prompted a more radical approach in design, with biological materials becoming a significant component for both designers and scientists equally since this transition in the design field cannot be ignored.

Biophilic design has progressed and broadened into practical applications from Biophilia theory, which was presented to the built environment by Fromm (1973) and Wilson (1984) by combining natural components in the modern living or non-living setting. Eckardt (1996) discussed the advantage of being close to natural environments (biophilia) in terms of human personal development. Kellert et al., (2008) corroborated the incorporation of nature in biophilic design to support human's well-being, regarding mind, emotion, and physical health. Biodesign (Myers, 2018) is described as renewable and sustainable system effort that includes living biological materials or ecosystems.

Bem (1972) developed a link between self-perception and behaviourist theory on how people form observations and hypotheses about their attitudes and behaviours toward objects and events. Merleau-Ponty (2004) examined perception by connecting the worlds of science, space, sensory items, animal life, self and other people's experiences, art and philosophy, and with the integration the classical and contemporary worlds. Fish (2010) defined perception as the relationship between mental states or experiences and visual experiences. Finally, from a scientific standpoint, Ware (2019) asserts that perception entails cognitive systems involved in seeing, thinking, and comprehending that shape our assumptions, beliefs, ideas, and knowledge about specific things or occurrences.

Understanding the perceptions, and emotional responses of users are important for design, and a number of researchers have explored this in relation to products, materials, these provide the foundation for the methodology we have adopted. Perez Mata et al. (2017 and 2019), Achiche and Ahmed-Kristensen (2011), have researched the perception of aesthetics in consumer objects and utilised Goldman's (1995) categories to classify consumers' perceptions to better understand how this knowledge can be represented in computational systems. Chatterjee and Vartanian (2016) and Melcher and Bacci (2013), stated that the conventional domains involving neuroaesthetics influence creative and artistic experiences include perception, emotion, attention, memory, and decision making. This is the expression of viewers' "objective" reactions toward fine arts, abstract art, faces, photographs of historical events, and other artworks or art objects. Other relevant studies in perception are by Dunston et al. (2002), DiSalvo et al. (2002) and Carozza (2016) where they conducted studies on Augmented Reality Computer Aided Drawing (AR-CAD), a human-robot interaction that was more focused on the initial understanding of facial features images of 48 humanoid robots and the design development of cybernetic hand (prosthetic hand) devices.

1.1. Research Aim

The research aims specifically to: investigate the emotional responses and perception of users to biophilic material and; how these are affected when the materials are embedded within a product. This study will also further clarify the user perception toward biophilia, biophilic design, bio-design, identifying purposes and sense of ownership of products incorporating biological materials.

2. Methodology

This research project was structured in eight stages (Figure 1), namely: 1) Designing a questionnaire, selecting an online platform (SurveyGizmo) and identifying the corresponding (six) main sections, 2) creating an initial compilation and classification of biological materials and related products, 3) setting up the online survey, 4) testing the online survey - small pilot study with 3 users, 5) obtaining ethical approval for the survey from the Universities ethics committee (Royal College of Art), 6) dissemination of the online survey through social media and emails, and 7) further development of the conceptual model based on results of two previous studies (Sayuti et. al 2015 and 2018). These earlier studies investigated emotional design, the perception and the rationale of integrating living organisms into furniture design, with a special focus on the designer's perspective. Data obtained from educators, students, Australian and international designers were compared and stratified by employing a pragmatic mixed-method approach. The conceptual model was also applied to the survey to identify the rationale and classify the purposes and functionalities of the biomaterials used in everyday designs (Sayuti et. al, 2020). The final stage 8) covered the analysis and discussion of the survey results to understand the emotional responses and perception of potential consumers towards biological elements.

https://doi.org/10.1017/pds.2022.205 Published online by Cambridge University Press

Figure 1. The Experimental Design Phases

To construct the survey, the researchers first identified the different types of living organisms/biomaterials that are embedded in existing product designs. These biological materials were then classified into four groups:

1. Artificial natural elements, which include images of nature such as photographs, graphics, painting, drawing, and others, as well as artificial plants, flowers, or grass.
2. A real natural element: plants such as moss, edible plants, flowers, and decorative plants, as well as cacti or succulents.
3. A real natural element: animals involving animals such as fishes, insects and other with due care, and
4. *Real natural element: microorganism* such as fungi, algae and beneficial bacteria (Figure 2 below).

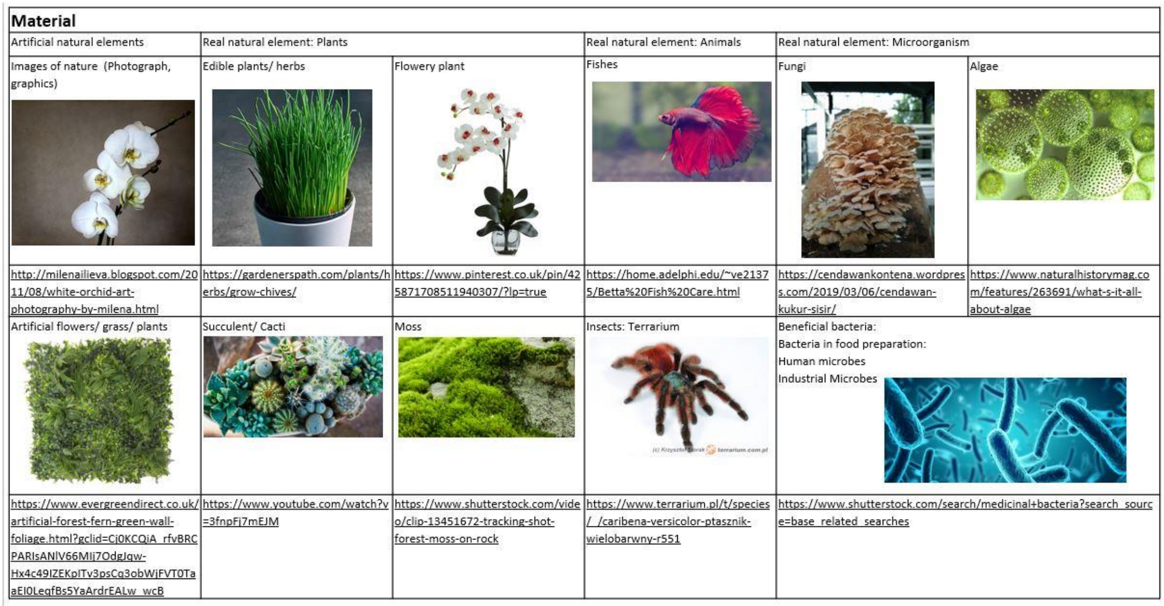


Figure 2. Examples of artificial and real biological materials used in the survey (Sayuti and Ahmed-Kristensen, 2020)

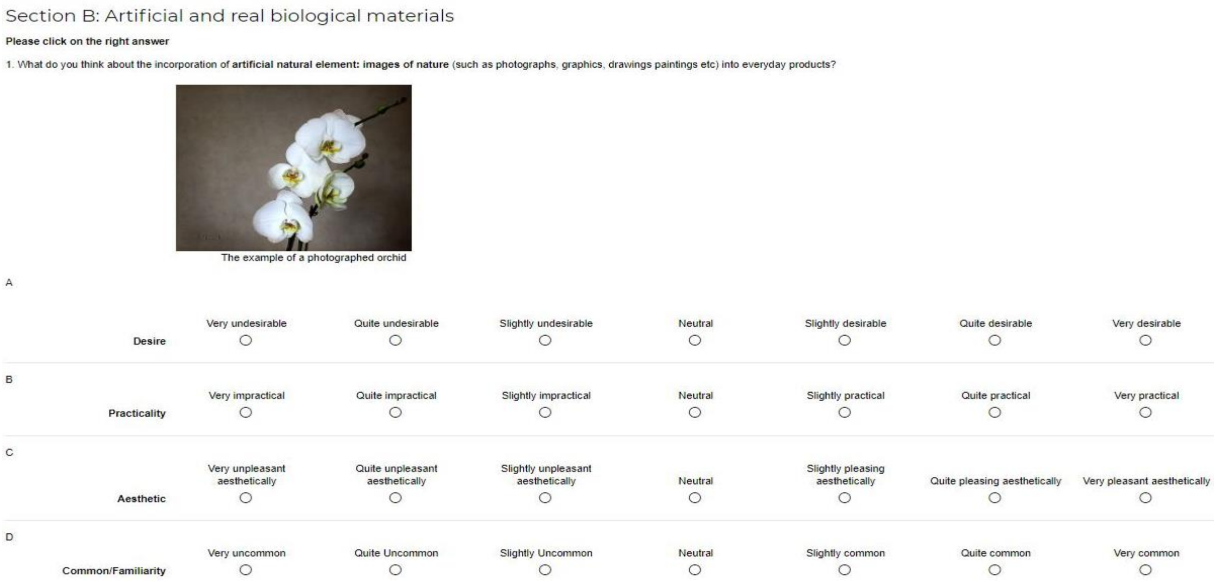
2.1. Questionnaire Design

A survey was used to collect respondents' perceptions and emotions about biological aspects included in designs. The survey collected information on how consumers or potential users perceive biological features in current design products, as well as their emotional response, and how this is influenced by the object's purpose, emotion, and practical application in existing designs. The questionnaire was designed to elicit comments from respondents. This consisted of six main sections: *A) Respondent background*, *B) Artificial and real biological materials* (please refer Figure 3 for the sample of the survey), *C) Emotional Design: Biological Materials*, *D) The purpose of biological elements*, *E) Existing Biophilic Design/Bio-design*, and *F. Biophilia, biophilic design, bio-inspired design and bio-design*. The questionnaire was composed of visual pictures of biological materials as well as current designs by selected designers, therefore no participants were exposed to any biomaterials. Participants were recruited using social media, and the survey was sent out via email.

https://doi.org/10.1017/pds.2022.205 Published online by Cambridge University Press

Participation was voluntary, and participants could opt out at any time throughout the survey. For this work, a total of 234 complete replies were gathered and analysed using SPSS version 25. This study adopted PrEmo in order to measure the emotional responses and a Likert scale to evaluate perceptions, using the approach of Perez Mata et al. (2013 and 2015)

This paper focuses on the survey section *B) Artificial and real biological materials which the questions on perception were asked to the respondents based on* 1) positive rating of desirable and a negative rating of undesirable, 2) positive rating of practicality or a negative rating of impracticality, 3) positive rating of pleasing aesthetically or a negative rating of unpleasing aesthetically, 4) positive rating of common/familiarity or a negative rating of uncommon/unfamiliarity as seen in the Figure 3 below. The mean scores use the scale of (-) 3; very, (-)2; quite, (-)1; slightly, 0; neutral.



Section B: Artificial and real biological materials

Please click on the right answer

1. What do you think about the incorporation of **artificial natural element: images of nature** (such as photographs, graphics, drawings paintings etc) into everyday products?

The example of a photographed orchid

A **Desire**	Very undesirable	Quite undesirable	Slightly undesirable	Neutral	Slightly desirable	Quite desirable	Very desirable
B **Practicality**	Very impractical	Quite impractical	Slightly impractical	Neutral	Slightly practical	Quite practical	Very practical
C **Aesthetic**	Very unpleasant aesthetically	Quite unpleasant aesthetically	Slightly unpleasant aesthetically	Neutral	Slightly pleasing aesthetically	Quite pleasing aesthetically	Very pleasant aesthetically
D **Common/Familiarity**	Very uncommon	Quite Uncommon	Slightly Uncommon	Neutral	Slightly common	Quite common	Very common

Figure 3. An example of questions in Section B on the perception of biological materials in everyday products

3. Results

3.1. Respondent Background

A total of 234 responses were received and analysed for this paper. Background data were collected on *Gender* (66.6% of female, 32.5% of male while 0.9% preferred not to answer), *Age* (ranging from 18-25 with 10.3%, 26 to 30 with 9.9%, 31 to 40 with 45% is the highest responses received from, 41 to 50 with 25.8%, while minimum responses received from 51 to 60 with 7.7% and 61 or older with 1.3%.). The respondents are from a Design and Non-design background with 38% (89 respondents) and 61.5% (144 respondents) respectively. Moreover, their cultural background (86.3% Asian, 9.9% White, 1.6% Mixed, 1.3% Other, 0.9% preferred not to answer and 0% Black/African- American). Almost all respondents have access to nature with 88.0%. 57.7% of the respondents prefer to experience nature outdoor while 40.2% preferred to experience both (outdoor and indoor) and only 2.1% preferred to experience it indoor. They spend time in nature mostly 2-3 times a week with 24.4%, 23.1% prefer once a month, 22.2% do it every day, 18.8% only spend once a week, 9.8% spend twice a month and 1.7% has no nature contact at all.

3.2. The Perception of Artificial and Real Biological Materials was Analysed

Eleven (11) artificial and real biological materials were identified and used in the questionnaire (Please refer to Table 1 for the guidance of symbol used in the data analysis). The respondents were asked to use a 7-point Likert Scale to rate the level of desirability (undesirable), practicality (impractical), aesthetically pleasing (unpleasant aesthetically) and the common/ familiarity

https://doi.org/10.1017/pds.2022.205 Published online by Cambridge University Press

(uncommon) for the incorporation of artificial and biological materials into everyday products. The results can be seen in Table 2 to Table 5 below are the descriptive analysis of the Mean value of the SPSS test. A mean score uses the scale of (-) 3; very, (-) 2; quite, (-) 1; slightly, 0; neutral, positive integers indicate an overall positive rating (e.g. desirable) and negative a negative rating (e.g. undesirable).

Table 1. Guidance of symbol used in the data analysis

The symbols used in the data analysis										
Images of nature	Artificial plants	Moss	Edible plants	Decorative plants	Succulent and Cacti	Fishes	Insects	Fungi	Algae	Bacteria

The symbols are taken from iconfinder.com, vectorstock.com, shutterstock.com and subscribed from the premium version of freepik.com.

3.2.1. *Materials positive for desirability*

The responses were analysed to understand the different perspectives regarding design and non-design background. The desirability of the materials was analysed; the findings showed that six materials received an overall positive level of desirability, which are *images of nature*, *moss*, *edible plants*, *decorative plants*, *succulent and cacti* and *fishes*. Four materials received a negative level of desirability (i.e., perceived as undesirable), namely *insects*, *fungi*, *algae*, and *bacteria* by the non-design and design group. However, fungi were perceived as neither desirable or undesirable by the design group. Artificial plants were perceived as neutral by both groups. These results are highlighted in yellow in Table 2 below.

The ANOVA test was applied to compare the significant differences in the Mean on the perception of two groups of respondents (comparing those with a background in design and non-design). From Table 2 below, the *images of nature*, *artificial plants*, *fishes* and *algae* were found to have significantly different responses, i.e. Sig. value (below 0.05) with 0.022, 0.013, 0.039 and 0.007 respectively. It was surprising that the bacteria result was not significant given the growing use bacteria within biodesign; it was expected that designers would have a greater level of acceptance for this kind of material.

Table 2. The analysis of Mean value, ANOVA and the non-parametric test on perception of desirability

Working Background		Images of nature	Artificial plants	Moss	Edible plants	Decorative plants	Succulent and Cacti	Fishes	Insects	Fungi	Algae	Bacteria
Non design	Mean	1.3472	0.7014	1.0486	1.7778	1.9444	1.3958	1.2867	-0.9861	-0.0634	-0.6429	-0.8056
Design		0.8764	0.1236	1.1236	1.5843	1.6292	1.4886	0.8315	-0.8202	0.1573	-0.0225	-0.7865
The ANOVA test for desirability												
Sig		0.022	0.013	0.725	0.248	0.061	0.623	0.039	0.490	0.311	0.007	0.939
Mann-Whitney U/ Wilcoxon W												
Asymp. Sig. (2-tailed)		0.011	0.015	0.891	0.163	0.072	0.929	0.017	0.452	0.403	0.006	0.994
a. Grouping Variable: Working Background												

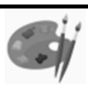
https://doi.org/10.1017/pds.2022.205 Published online by Cambridge University Press

The non-parametric test (Mann-Whitney) was applied due to the unequal distribution of the number of respondents between the Design and Non-design groups. The respondents are from a Design and Non-design background with 89 respondents and 144 respondents respectively. The Mann- Whitney test has verified the significance value for the *images of nature, artificial plants, fishes* and *algae* where these materials found to have significantly different responses, i.e. Sig. value (below 0.05) with 0.011, 0.015, 0.017 and 0.006 Asymp. Sig. (2-tailed) value as seen in Table 2 above.

3.2.2. Materials positive for Practicality

The findings showed that four materials were perceived to have a positive level of practicality: *nature images, edible plants, decorative plants*, as well as *succulents and cacti*. Three materials received negative levels of practicality (i.e., perceived as impractical), which are *insects, algae* and *bacteria* for both groups. Moreover, fishes were also perceived as impractical by designer group. Artificial plants, moss, and fishes were perceived as close to neutral (neither practical or impractical) by non-design group while design group viewed the decorative plants as neutral. Fungi were perceived as neutral (neither practical or impractical) by both groups. These results are highlighted in yellow in Table 3 below.

Table 3. The analysis of Mean value, ANOVA and the non-parametric test on perception practicality

Working Background												
Not design	Mean	1.2431	.8392	.5278	1.6597	1.4306	1.2238	.9167	-.9716	.0420	-.60417	-.7214
Design		.7500	.4831	.3708	1.1798	.8989	1.0000	-.0112	-.9326	.0899	-.08989	-.5618
The ANOVA test for practicality												
Sig		0.008	0.094	0.465	0.008	0.003	0.286	0.000	0.859	0.823	0.019	0.515
Mann-Whitney U/ Wilcoxon W												
Asymp. Sig. (2-tailed)		0.012	0.059	0.309	0.008	0.009	0.233	0.000	0.743	0.951	0.013	0.547
a. Grouping Variable: Working Background												

The ANOVA test was applied to compare the significant differences in the Mean on the perception of the practicality of the biological materials. From Table 3, five biological materials were identified, the images of nature, edible plants, decorative plants, fishes and algae were found to have significantly different responses, i.e., Sig. value (below 0.05) with 0.008, 0.008, 0.003, 0.000 and 0.019 respectively.

The Mann-Whitney test has verified the significance value for the significant responses towards six materials; *images of nature, artificial plants, edible plants, decorative plants, fishes* and *algae* where these materials found to have significantly different responses, i.e. Sig. value (below 0.05) with 0.012, 0.059, 0.008, 0.009, 0.000 and 0.013 Asymp. Sig. (2-tailed) value as seen in Table 3 above to be embedded into daily products.

3.2.3. Materials Positive for Aesthetically Pleasing

From the analysis, six materials received a positive perception level of "aesthetically pleasing"; these were: *images of nature, moss, edible plants, decorative plants, succulent and cacti* and *fishes*. Four materials received a negative level of "aesthetically pleasing" (i.e. perceived as unpleasing aesthetically) which are *insects, algae* and *bacteria* by the non-design group, while only *insects* and *bacteria* perceived negatively by the design group. Artificial plants were perceived as close to neutral

https://doi.org/10.1017/pds.2022.205 Published online by Cambridge University Press

(neither pleasing aesthetically or unpleasing aesthetically) by both groups. Fungi and algae were perceived as neutral by design group. Results are highlighted in yellow as in Table 4 below.

Table 4. The analysis of Mean value, ANOVA and the non-parametric test on perception of aesthetic

Working Background												
Not design	Mean	1.5486	.8125	1.0909	1.6761	1.9371	1.4167	1.3706	-.8542	-.1250	-.6643	-.9577
Design		1.4318	.4318	1.2697	1.6705	1.7528	1.5455	1.2921	-.7079	.1798	.1348	-.6067
The ANOVA test for aesthetic												
Sig		0.477	0.078	0.385	0.973	0.262	0.493	0.692	0.530	0.165	0.000	0.138
Mann-Whitney U/ Wilcoxon W												
Asymp. Sig. (2-tailed)		0.550	0.103	0.524	0.596	0.467	0.518	0.633	0.539	0.170	0.001	0.138
a. Grouping Variable: Working Background												

From Table 4, the ANOVA test only shown a significant different response towards *algae* with 0.000 value as it shows disagreement of responses between both groups.
The Mann-Whitney test verified the significance value for *algae* with Asymp. Sig. (2-tailed) value of 0.001 as shown in Table 4 above.

3.2.4. Materials Positive for Common/ Familiarity

The familiarity of the materials for the user was analysed, the findings showed that six materials received a positive level of common/familiarity from the non-design group, these findings were not surprising: nature images, artificial plants, edible plants, decorative plants, succulent and cacti and fishes. Meanwhile, the design group has neutral responses towards artificial plants, moss, edible plants, succulent and cacti and fishes. As expected, four materials received a negative level of familiarity (i.e., perceived as uncommon), such as insects, fungi, algae and bacteria. These results highlighted in yellow as in Table 5 below.

Table 5. The analysis of Mean value, ANOVA and the non-parametric test on perception of common/ familiarity

Working Background												
Not design	Mean	1.4444	1.1197	.5455	1.3986	1.5070	1.0972	1.1197	-.8380	-.4266	-.7569	-.7762
Design		1.1236	.6742	.0230	.7955	1.3864	.9213	.3708	-1.1818	-.7640	-.9663	-1.1124
The ANOVA test for common/ familiarity												
Sig.		0.053	0.017	0.015	0.001	0.493	0.391	0.000	0.107	0.105	0.335	0.176
Mann-Whitney U/ Wilcoxon W												
Asymp. Sig. (2-tailed)		0.022	0.023	0.007	0.000	0.975	0.493	0.000	0.133	0.128	0.429	0.221
a. Grouping Variable: Working Background												

Images of nature, *artificial plants*, *moss*, *edible plants* and *fishes* were found to have significantly different responses between familiarity and neutral, i.e. Sig. value with 0.053, 0.017, 0.015, 0.001 and

https://doi.org/10.1017/pds.2022.205 Published online by Cambridge University Press

0.000 respectively (please refer Table 5 above). These materials are generally known or commonly used or incorporated in any product or urban environment/ living space.
The Mann- Whitney test showed the significant Asymp. Sig. (2-tailed) value of 0.022, 0.023, 0.007, 0.000 and 0.000 respectively for *images of nature, artificial plants, moss, edible plants* and *fishes* as in Table 5.

4. Conclusions, Discussion and Future Research

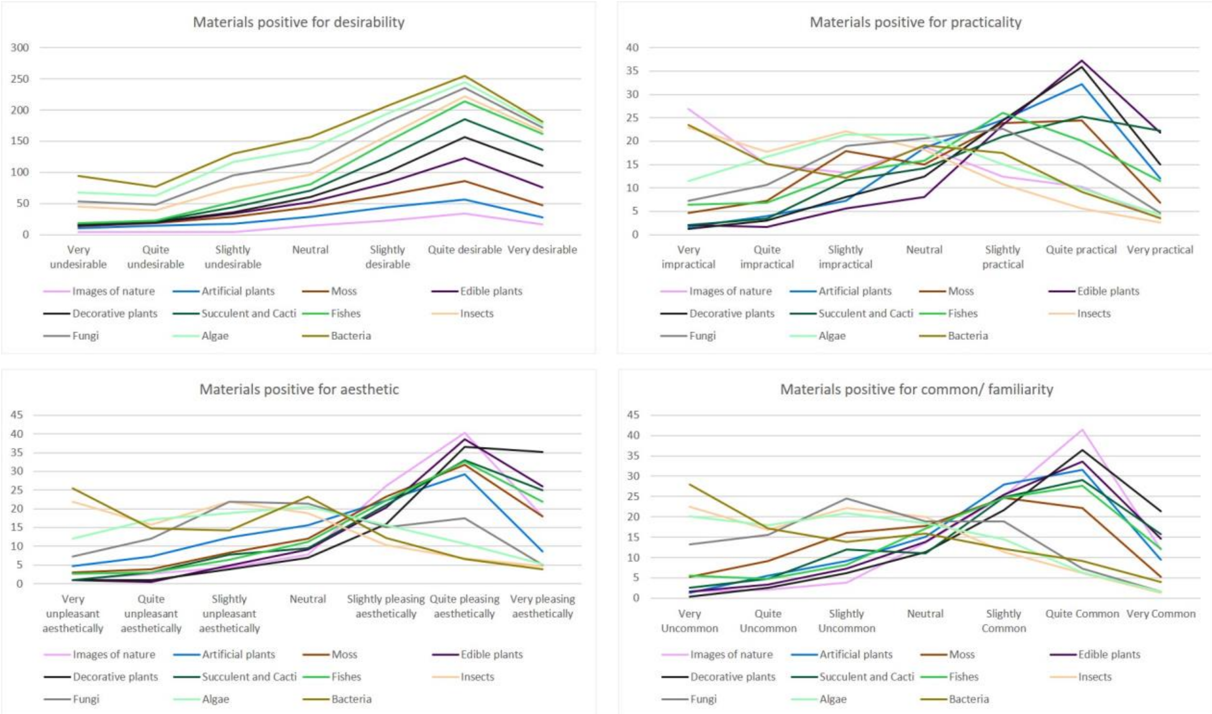


Figure 4. The visual presentation of data to compare relative differences of the perception of respondents towards biological material across all materials

An empirical study was conducted using an online survey to investigate the perception of biological materials. The primary tool used to convey information to potential customers was a bespoke online survey. The discovery of these perceptions may be used to inform new creative approaches to new designs and materials, allowing data to be collected in greater quantities than traditional ways. Gunn (2002), Roth (2006), Mahon-Haft and Dillman (2010), White and Gatersleben (2011), Hofelich Mohr et.al (2016) and others were utilised as models. Our earlier work discussing biological materials within emotion and perception in design (Sayuti and Ahmed-Kristensen, 2020), bio-related genres (Sayuti et.al, 2021a), purposes and ownership of biological materials (Sayuti et.al, 2020), furniture design with living organisms (FDLOs) (Sayuti et.al, 2015, 2018 and 2021b) can be referred to for further understanding.
Images of nature showing artificial plants, moss, edible plants, ornamental plants, succulent and cactus, fishes, insects, fungi, algae, and bacteria were classified into eleven artificial and real biological materials. The 7-point Likert Scale was used to assess the desirability, practicality, aesthetically pleasing, and common/familiarity of integration of these artificial and biological elements into everyday products. The ANOVA test was used to assess the significant differences in the Mean of two groups of respondents' perceptions from the design and non-design background. Figure 4 above illustrates the visual presentation of data to compare relative differences of the perception of respondents towards biological material across all materials. The overall findings in the graph shows the materials positive for all biological materials and the detailed explanation on findings were discussed in *Results* previously.
For the desirability of the materials, the findings showed that four materials received a positive level of desirability, i.e., moss, edible plants, decorative plants and succulent and cacti and another four

https://doi.org/10.1017/pds.2022.205 Published online by Cambridge University Press

materials received a negative level of desirability which are insects, fungi, algae, and bacteria by the non-design and design group.

For practicality, four materials were perceived positively which are nature images, edible plants, decorative plants, succulents and cacti while three materials received negative responses, which are insects, algae and bacteria for both groups. However, fishes were perceived as impractical by designer group.

For the category “aesthetically pleasing”, six materials were perceived positively which are images of nature, moss, edible plants, decorative plants, succulent and cacti and fishes. As can be expected, four materials perceived negatively: insects, fungi, algae and bacteria by the non-design group, whereas for the design group the only negative perception existed towards insects and bacteria.

Lastly, six materials are perceived positively for common/familiarity from the non-design group, these were unsurprisingly: nature images, artificial plants, edible plants, decorative plants, succulent and cacti and fishes. However, artificial plants, moss, edible plants, succulent and cacti and fishes gained neutral responses from the design group. This may be due to the common use of these materials in existing designs. As expected again, insects, fungi, algae and bacteria were perceived negatively in terms of “familiarity” as these materials are rarely used in designs or they are still in conceptual or experimental stage – as some of these materials are not available for the public yet.

These materials can be seen to have different connotations and understanding by respondents towards their function and common use in daily life. The differences of perception towards these materials might be affected by the respondents’ age, gender, cultural background and working background. Other reasons to be considered might be the safety of materials to the users, the additional time investment to be able to use these materials, the availability of the materials in certain areas or regions, people’s beliefs and experiences towards these materials. Overall, it can be concluded that the designer’s perception of biological materials tends to be more positively connotated than the one from non-designers. The reason might be that designers usually start experimenting with new or alternative materials before the end consumers is exposed to those materials, and thus have a higher degree of familiarity and acceptance. Desirability of biomaterials seems to be not just related to familiarity, but also a negative perception, thus suggests there is some work to be done before biomaterials can be fully accepted by users, which is beyond the exposure of the materials.

Future research could explore particular properties of products in detail (Johnson et al. 2003), or shift the focus towards pleasurability aspects (Blijlevens et al. 2017, Lin et al. 2020).

This study is part of a larger project; future work will involve investigating the perception of biological materials while optimizing products towards various purposes, such as usefulness, aesthetics, and experience. Furthermore, this experiment may be expanded by incorporating real living biological materials into current products to examine the direct experience of living materials.

References

Achiche, S. & Ahmed-Kristensen, S. (2011) “Genetic Fuzzy Modelling of User Perception of 3D Shapes”. *Journal AIEDAM Artificial Intelligence Engineering Design and Manufacturing*. 25, pp 93-107.

Bem, D. J. (1972). "Self-Perception theory". *Advances in Experimental Social Psychology* 6 (1): 1–62. https://doi.org/10.1016/s0065-2601(08)60024-6

Blijlevens, J., Thurgood, C., Hekkert, P., Chen, L. L., Leder, H., & Whitfield, T. W. (2017). "The Aesthetic Pleasure in Design Scale: The development of a scale to measure aesthetic pleasure for designed artifacts". Psychology of Aesthetics, *Creativity, and the Arts*, 11(1), 86. https://doi.org/10.1037/aca0000098

Carrozza, M. C., Cappiello, G., Micera, S., Edin, B. B., Beccai, L., & Cipriani, C. (2006). "Design of a cybernetic hand for perception and action". Biological Cybernetics, 95 (6), 629-644. https://doi.org/10.1007/s00422-006-0124-2

Chatterjee, A., and Vartanian O. (2016). "Neuroscience of aesthetics". *Annals of the New York Academy of Sciences.* 1369 (1): 172–194. https://doi.org/10.1111/nyas.13035

DiSalvo, C. F., Gemperle, F., Forlizzi, J., & Kiesler, S. (2002). "All robots are not created equal: the design and perception of humanoid robot heads", In 4th conference on Designing interactive systems: processes, practices, methods, and techniques. https://doi.org/10.1145/778712.778756

Dunston, P., Wang, X., Billinghurst, M., & Hampson, B. (2003). "Mixed reality benefits for design perception". *Nist Special Publication SP*, 191-196. https://doi.org/10.22260/isarc2002/0030

Eckardt, M. H. (1996)." Fromm’s Humanistic Ethics and the Role of the Prophet". *A Prophetic Analyst: Erich Fromm’s Contributions to Psychoanalysis*, 151-165.

https://doi.org/10.1017/pds.2022.205 Published online by Cambridge University Press

Franklin, K. and Till, C. (2018). Radical matter: rethinking materials for a sustainable future. Thames & Hudson Incorporated., A. (1995) *Aesthetic value*. Westview Press, Colorado.
Gunn, H. (2002). "Web-based surveys: Changing the survey process". First Monday, 7(12). https://doi.org/10.5210/fm.v7i12.1014
Hofelich Mohr, A., Sell, A., & Lindsay, T. (2016). "Thinking inside the box: Visual design of the response box affects creative divergent thinking in an online survey". Social Science Computer Review, 34(3), 347-359. https://doi.org/10.1177/0894439315588736
Johnson, K.W., Lenau, T. and Ashby, M.F. (2003). "The aesthetic and perceived attributes of products". *In Proceedings of ICED 03, the 14th International Conference on Engineering Design, Stockholm*.
Kellert, S. R., Heerwagen, J., & Mador, M. (2008). Biophilic design: The theory, science and practice of bringing buildings to life. John Wiley & Sons.
Lin, Z., Sommer, B. and Ahmed-Kristensen, S., (2020). "IoT product pleasurability-Investigating the pleasurable user experiences between conventional products and IoT products through watches". In International Conference on ArtsIT, Interactivity and Game Creation, Springer, Cham, 394-408. https://doi.org/10.1007/978-3-030-73426-8_24
Merleau-Ponty, M., Davis, O., & Baldwin, T. (2004). *The world of perception*. Cambridge University Press.
Melcher, D. & Bacci, F. (2013). “Perception of emotion in abstract artworks: A multidisciplinary approach.” In Progress in Brain Research, Elsevier, Amsterdam. vol. 204, 191–216. https://doi.org/10.1016/B978-0-444-63287-6.00010-5.
Mahon-Haft, T. A., & Dillman, D. A. (2010). "Does visual appeal matter? Effects of web survey aesthetics on survey quality". *In Survey Research Methods*. Vol. 4, No. 1, pp. 43-59.
Myers, W. (2018). Bio design: nature, science creativity. Revised and expanded version. Thames and Hudson.
Mata, M.P., Ahmed-Kristensen, S. and Shea, K. (2019). "Implementation of design rules for perception into a tool for three-dimensional shape generation using a shape grammar and a parametric model". *Journal of Mechanical Design*, vol 141, 011101-1, https://doi.org/10.1115/1.4040169
Mata, M.P., Ahmed-Kristensen, S., Brockhoff, P.B. and Yanagisawa, H. (2017). "Investigating the influence of product perception and geometric features. Research in Engineering Design", 28(3), pp.357-379, https://doi.org/10.1007/s00163-016-0244-1
Roth, M. (2006). "Validating the use of internet survey techniques in visual landscape assessment—An empirical study from Germany". *Landscape and Urban Planning*, 78(3), 179-192. https://doi.org/10.1016/j.landurbplan.2005.07.005
Sayuti, N. A. A., & Ahmed-Kristensen, S. (2020). "Understanding emotional responses and perception within new creative practices of biological materials", *Proceedings of the Sixth International Conference on Design Creativity* (ICDC 2020) University of Oulu, Finland, August 27-28, 2020, pp. 144-15. https://doi.org/10.35199/ICDC.2020.18
Sayuti, N. A. A., Sommer, B., Ahmed-Kristensen, S., (2020). "Identifying the purposes of biological materials in everyday designs". Environment-Behaviour Proceedings Journal, 5(15), *Conference on AMEABRA International Virtual Conference on Environment-Behaviour Studies, 2ndSeries Shah Alam Malaysia, 02-03 Dec* 2020, 5(15), 29-37. https://doi.org/10.21834/ebpj.v5i15.2479
Sayuti, N. A. A., Sommer, B., Ahmed-Kristensen, S. (2021a). "Bio-related Design Genres: A Survey on Familiarity and Potential Applications". In: Brooks A., Brooks E.I., Jonathan D. (eds) Interactivity and Game Creation. ArtsIT 2020. Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering, vol 367. Springer, Cham. https://doi.org/10.1007/978-3-030-73426-8_23
Sayuti, N. A. A., Elivio Bonollo, and Carlos Montana-Hoyos. (2021b). "Emotional Responses, Perceptions, and Preferences toward Furniture Design Based on Living Organisms". The International Journal of Designed Objects, 15 (2): 1-20. https://doi.org/10.18848/2325-1379/CGP/v15i02/1-20
Sayuti, N. A. A., Montana–Hoyos, C., & Bonollo, E. (2018). "Biophilic Design: Why do designers incorporate living organisms in furniture design?", *Conference Proceeding the Fifth International Conference on Design Creativity (ICDC2018). University of Bath, UK. February 2018*.
Sayuti, N., Montana-Hoyos, C., & Bonollo, E. (2015). "A study of furniture design incorporating living organisms with particular reference to biophilic and emotional design criteria". *Academic Journal of Science*, 4(1), 75-106.
Ware, Colin. (2019). Information Visualization: Perception for Design. Burlington, MA: Morgan Kaufmann.
White, E. V., & Gatersleben, B. (2011). "Greenery On Residential Buildings: Does It Affect Preferences and Perceptions of Beauty?" *Journal of Environmental Psychology*, 31(1), 89-98. https://doi.org/10.1016/j.jenvp.2010.11.002
Wilson, E. O. (1984). *Biophilia*. Harvard University Press.