Living with living artefacts: Six concepts for designing user acceptance of living artefacts

Simone van den Broek  
*Centre of Applied Research for Art, Design and Technology, Avans University of Applied Sciences*

Alwin de Rooij  
*Centre of Applied Research for Art, Design and Technology, Avans University of Applied Sciences*

Michel van Dartel  
*Centre of Applied Research for Art, Design and Technology, Avans University of Applied Sciences*

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Living with living artefacts: Six concepts for designing user acceptance of living artefacts

Simone van den Broek*, Alwin de Rooij, Michel van Dartel
Centre of Applied Research for Art, Design and Technology, Avans University of Applied Sciences
*corresponding e-mail: sjce.vandenbroek@avans.nl
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Abstract: Bio-designers are exploring how living organisms can become vital aspects of the design and use of an artefact. These new living artefacts have qualities, needs, design opportunities and relationships with the user that differ from nonliving artefacts. To design for user acceptance of living artefacts into daily life, designers must develop an understanding for why a user wishes to live with living artefacts. This starts with an understanding of why humans have been living with other living beings throughout history. These reasons have been examined through a semi-systematic review of literature across diverse research fields. Qualitative thematic analysis suggests that the benefits of Biophilia, Care and Meaning and those of Performing tasks, Source of material and Knowledge & skill, are essential to why humans live with other living beings. Based on these six concepts, eight design guidelines are proposed for designing user acceptance of living artefacts into daily life.

Keywords: bio-design; living artefacts; user acceptance; symbiosis

1. Introduction
Humankind has always lived with and among different living organisms. They are beings that host many different organisms within them. However, in the development from a hunter-gatherer society to a modern-day society, in which humans predominantly live in a human-engineered world, humans have increasingly less contact with other living organisms (Kellert & Calabrese, 2015). Currently, through the practice of Bio-design (see, e.g., Myers & Antonelli, 2018) new methods are being developed to integrate living organisms as vital aspects of both the design and use of an artefact, resulting in the creation of living artefacts (Karana et al., 2020). Living artefacts are a new way for organisms to be further integrated into the daily life of humans. They create opportunities for novel product experiences and have qualities, needs and design opportunities that differ from nonliving artefacts (Karana et al., 2020). Consequently, this occasions different relationships between users and living artefacts and inspires different reasons for wishing to interact with an artefact.
Figure 1 illustrates examples of how product design currently integrates living organisms into the design and use of a product that previously consisted exclusively of nonliving materials. The first picture (left) shows the project Ambio by Teresa van Dongen, a lamp that provides light through the use of bioluminescent bacteria. The second picture (middle) shows the project Living Cocoon by Loop Biotech, a coffin made from mycelium that is biodegradable and allows the body’s decomposition to become a source for new life. The third picture (right) shows the project Biolume by Teresa van Dongen, a design inspired by oil lamps running on microorganisms that purify water while continuously excreting electrons that can be used as source of energy for the production of light. Living artefacts do not only provide new design opportunities but also require users to provide for the design in new ways. For instance, users have to provide a form of care and a suitable habitat for the living artefact to live and thrive within (Karana et al., 2020). In return, the artefact provides humans with a range of benefits, which will be explored further in this paper.

Figure 1 Examples of designs that are alive during the use of the product. Ambio by Teresa van Dongen (left) Living Cocoon By Loop (middle) and Biolume by Teresa van Dongen (Photo: Wouter Koozen, BlickFänger (right)).

While many designers and researchers are currently exploring the potential of living materials for new product designs and considering ways to take ‘livingness’ into account during the design process, little attention has so far been given to their user acceptance. This is remarkable, considering that these products change a user’s relationship to the product from one of mere use to one of co-living with the product. This paper explores what bio-designers should take into account, with respect to the user acceptance of a living artefact and its integration into daily life. To design for the user acceptance of living artefacts into daily life, designers need to understand why users would wish to live with other living beings. A semi-systematic literature review has been conducted to examine the research question:

‘Why do humans live with other living beings?’

To address this question it is important to first define the notions of ‘being alive’, ‘other living being’ and ‘living together’, as well as to elaborate on why humans in particular seem to demonstrate a seemingly innate tendency to live with other living beings (Section 2). Through conducting the semi-systematic review and qualitative thematic analysis (Section
3), six concepts for why humans live with other living beings were distilled from the literature (Section 4). On the basis of these, a preliminary set of guidelines is proposed that can support designing for the user acceptance of living artefacts in daily life (Section 5). This with the intent to make it easier for bio-designers to create living artefacts that people would want to use and live with.

2. Living in symbiosis

To explore the different reasons behind human tendencies to live with other living beings, it first has to be established what it means to be alive, what another living being is and what it means to live together. According to Jones & Jones (2014) something is alive when it has the ability to move, grow, respire, detect and respond to changes in environment, reproduce, excrete and take in nutrition. Therefore, in the below, all beings that have the above abilities and are not human are referred to as ‘other living beings’. The formulation of ‘other living beings’ has been taken as to refer both directly to a living organism as well as refer to a living artefact. A living artefact in itself is not directly alive but as habitat enables a certain organism to live within it, the living artefact is the medium through which a user experiences the living aesthetics of the artefact (Karana et al., 2020).

When humans live together with other living beings, the human and the other living being share a symbiotic relationship: a state that can be mutualistic, commensalistic, or parasitic (Wilkinson, 2001). In a mutualistic symbiosis, both living beings enjoy reciprocal benefits from the symbiosis, while in a commensalistic symbiosis one living being benefits from the symbiosis and the other living being does not. In a parasitic symbiosis the living being that does not benefit from the symbiosis is harmed by it. In short, living beings live together because at least one of them benefits from the symbiotic state in which they live.

Humans live with other living beings because they consciously or subconsciously benefit from the symbiotic state and have learned how they can harvest this relationship to aid in their survival (Hartig et al., 2010). This means that, in the context of designing living artefacts, the symbiosis between a human and another living being must be mutualistic, commensalistic or parasitic with the benefit being for the human that chooses to commit to the symbiotic relationship. However, for a symbiotic relationship to be sustainable, it cannot be parasitic (Peacock, 2011). For a user to accept new living artefacts into their daily life it must be clear for the user how this symbiosis would benefit them.

3. Methodology

To explore why humans would want to live with living artefacts, designers must first develop an understanding for why humans wish to live with other living beings. To establish this, the research question ‘Why do humans live with other living beings?’ has been formulated. For this question, a semi-systematic literature review (Snyder, 2019) has been conducted, followed by qualitative thematic analysis(Braun & Clarke, 2006) on a corpus of 60 works
around this topic. A semi-systematic review was used so that the wide variety of fields that address this topic could be taken into account during the research process. After the semi-systematic review, a qualitative thematic analysis based on the grounded theory (Khan, 2014) was conducted to determine the main themes, concepts and classifications found in the selected literature. Through this approach a broad variety of findings and perspectives on the research question could be taken into account and the gathered information made coherent and applicable to the formation of design guidelines for designing user acceptance of living artefacts into daily life.

The literature used in the review has been selected based on the inclusion and exclusion criteria described in table 1. The database of the educational search engine Kaluga has been used to search for literature that fits these selection criteria. The identification of literature was done in two rounds. The first round was approached by using search terms derived from the research question (see figure 2). After a quick screening of the found literature in the first round of identification additional search terms were added derived from the found literature (see figure 2). Through the process of the two identification rounds 68 pieces of literature were found.

### Table 1  Inclusion and exclusion criteria

<table>
<thead>
<tr>
<th>Inclusion criteria</th>
<th>Exclusion criteria</th>
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<tr>
<td>The literature is an Paper or a book publication that writes about the connection between humans and another living being.</td>
<td>The literature is an Paper or a book publication that does not write about the connection between humans and another living being.</td>
</tr>
<tr>
<td>The literature supports made claims with conducted research or references.</td>
<td>The literature does not supports made claims with conducted research or references.</td>
</tr>
<tr>
<td>The connection between humans and another living being is the main topic of the text.</td>
<td>The connection between humans and another living being is not the main topic of the text.</td>
</tr>
<tr>
<td>Papers published (in print or online) in a peer-reviewed journal or scholarly book.</td>
<td>Papers published by other sources such as local authorities, private individuals and private companies.</td>
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After fully screening all 68 pieces of literature, 13 pieces of literature were excluded because they met one or more of the exclusion criteria. Furthermore, 5 pieces of literature were added from references. This resulted in 60 eligible pieces of literature from a wide range of fields (see figure 2).

The qualitative thematic analysis was conducted on the selected 60 pieces of literature to determine what themes, concepts and classifications the literature describes about the research question. Within each piece of literature all described reasons for why humans live with other living beings were highlighted. These individual reasons were then used as input for the qualitative thematic analysis. Given the qualitative thematic analysis is based on the grounded theory, the process itself was a continuous iterative process of connecting and comparing found data. See figure 3 for an overview of the outcomes of the thematic analysis.
Through conducting the qualitative thematic analysis, it became clear that current literature describes six main concepts for why humans live with other living beings. Furthermore, it became clear that a concept could be classified either as hedonic or utilitarian. The terms hedonic and utilitarian are drawn from Chitturi et al. (2008); within this context, the term hedonic benefits refers to the ways humans interpret aesthetic, experiential and enjoyment-related stimuli, while utilitarian benefits refers to functional, instrumental and practical benefits. The six main concepts found through the literary review are the hedonic benefits; Biophilia, Care and Meaning and the utilitarian benefits; Performing tasks, Source of Material and Knowledge & skill (see figure 3). Section 4 will further explore and define the six concepts for why humans live with other living beings.
4. Benefits of living with other living beings

Humans live with other living beings because they consciously and/or subconsciously benefit from this relationship (Section 2). This symbiosis enables them to do or experience something. As a result of a semi-systematic review on the research question ‘Why do humans live with other living beings?’ and a qualitative thematic analysis on 60 pieces of literature, it was found that current literature describes six concepts for why humans live with other living beings (Section 3). These six concepts are the three hedonic benefits of Biophilia, Care and Meaning, and the three utilitarian benefits of Performing tasks, Source of material and Knowledge & skill (see figure 3).

Often the experienced benefits of living with other living beings will be a mixture of hedonic and utilitarian benefits and multiple benefits can be experienced at the same time. Which benefits are experienced will depend on the particular human being, the social and cultural setting they are part of and the specific other living being in question (Hartig et al., 2010). The following paragraphs further explore each of the six concepts individually, with examples and explanations.

4.1 Biophilia

One of the most prominent benefits for humans to live with other living beings is Biophilia. Biophilia states that humans have an inherent subconscious need to connect to life and lifelike processes (Wilson, 1984). Evolutionarily speaking an environment with a high diversity in natural and living elements would lead to more opportunities for survival. This has shaped the human brain and is why humans continue to find the natural world and other living beings aesthetically appealing (see figure 4) and feel an innate to connect with and be close to them (Zaremba & Smoleński, 2000).

The importance of Biophilia becomes very clear in health studies that have been done on the effects of living and lifelike processes on humans. Numerous studies have determined that being exposed to living beings results in increased psychological (Zaremba & Smoleński,
2000) and physical (Kellert & Calabrese, 2015) well-being. For instance, on a psychological level, it can help humans to experience a higher level of intrinsic aspirations and lower valuing of extrinsic aspirations in their lives (Weinstein et al., 2009), lower rates of depression (Shanahan et al., 2016), improve mood and life satisfaction (Capaldi A. et al., 2014), decrease anxiety and rumination (Bratman et al., 2015), improve attention restoration (Hartig et al., 2010), reduce stress (van den Berg et al., 2015) and reduce mental fatigue (Shanahan et al., 2016). On a physical level, it can help humans to lower high blood pressure rates (Shanahan et al., 2016), live a healthy lifestyle that includes sufficient exercise (Grabbe et al., 2013; Serpell, 1991) and healthy eating habits (Grabbe et al., 2013; van Lier et al., 2017).

4.2 Care
Another clear benefit of living with other living beings is that it fulfils the inherent human need of giving and receiving care. Caring is a combination of affective concern (caring about) and practical action (caring for) (Jax et al., 2018). Caring actions are most naturally motivated by the caring feelings humans have towards something, other living beings, environments or artefacts. When it comes to a caring relationship between humans and other living beings, humans are most often both caregiver and care receiver (Jax et al., 2018; Karana et al., 2020). The caring relationship offers the human and the other living being certain benefits that contribute to their survival and well-being (Knight, 2018).

Caring for another living being can fulfil certain social needs humans have (see figure 5). This, for example, can be seen in pet owners (Staats et al., 2008). A pet can become a friend and companion to its owner (Maher & Pierpoint, 2011; Zaremba & Smoleński, 2000). Humans can even start viewing and treating animals (Knight, 2018; Hirschman, 1994) or other living beings (Tam et al., 2013) as a human being through the process of anthropomorphism (Archer, 1997). For instance, this can be observed in the way some people give their plants names and talk to them as though they might discern what is expressed.

**Figure 5** Other living beings that are cared for by humans. (Photo’s: Helena Lopes(left), Jonathan Borba (middle left), Ketut Subiyanto(middle right), Anna Shvets(right)).
Caring for other living beings can also enable social interaction and connection between humans (van Lier et al., 2017) and improve mental well-being (Grabbe et al., 2013). For instance, in the study of van Lier et al., (2017) they reported that young adults who are part of a communal gardening space have better social relationships, neighbourhood connection, and emotional well-being. Gardening gives them the opportunity to spend quality time with adults, like parents or teachers, and contribute something valuable to their families or local community. In the study of Grabbe et al., (2013) where women currently without a home took part in a gardening project, the participants reported that caring for the garden resulted in the interruption of negative ruminations, offered stress relief, social inclusion and self-actualisation. This contributed to their rehabilitation and inclusion within society.

4.3 Meaning

Humans can give or experience a certain meaning when it comes to other living beings. The meaning given or experienced by humans is dependent on many different personal (Baumeisterm & Bushman, 2017) and social (Shove et al., 2012) factors and can, for instance, be experienced in the form of religious and spiritual beliefs, mindfulness, symbolisms and metaphors, status or self-expression and creativity.

**Religious and spiritual beliefs.** The meanings of other living beings play an important part in many if not all religious and spiritual beliefs. For instance, animals play a part in shape-shifting beliefs, animal totems, animal oracles (Knight, 2018) and reincarnation (Hui & Coleman, 2012). Animals have been and are still used as sacrifices to appease gods or spirits (Knight, 2018). Some evidence shows that the first domesticated animals were not domesticated for materialistic reasons but for their use in rituals (Shanklin, 1985). There are examples of sacred animals, such as the sacred place of cows in India, that are treated with the utmost respect and are not to be eaten (Shanklin, 1985). Furthermore, gardens and animals are an important part of theological tales like the garden of Eva and Adam (Francis & Hester Jr., 1992). Gardens can also be a place for spirituality where one meditates, reflects and makes contact with their spiritual entity (Francis & Hester Jr., 1992).

**Mindfulness.** Mindfulness is the practice of consciously acknowledging the present moment, both on a physical and psychological level, without any judgment (Carmody et al., 2008). Mindfulness enables humans to recognise intrinsic needs and better regulate themselves towards meeting those needs (Howell et al., 2011). The meaning that humans give to or experience when relating to other living beings has a significant correlation to practicing mindfulness (Howell et al., 2011). People who feel more connected to and experience more meaning when relating to other living beings find it easier to practice mindfulness.

**Symbolisms and metaphors.** Other living beings can portray certain symbolisms (Farca et al., 2015; Huss et al., 2017; Werness, 2006) and metaphors (Shanklin, 1985) that convey certain qualities or values that have significance for humans. One specific living being can portray multiple metaphors or symbolisms and these metaphors and symbolisms are not
universally recognised by all humans as these are dependent on particular societal and cultural influences. Metaphors are most often based on the perception of parallels between humans and other living beings like character traits, physical qualities or functional equivalence (Shanklin, 1985). An example of a metaphor about other living beings is the saying ‘strong as a horse’ which refers to something being very physically strong or the metaphor ‘delicate as a flower’ which refers to something being simultaneously fragile and beautiful. An example of a symbolic meaning about other living beings is how a white dove symbolises the Holy Spirit in Christianity and at the same time, a white dove symbolises peace in modern western society. In some cultures, every living being or entity - plant, animal and otherwise has meaning while other cultures only assign meaning to very specific plants, animals or other living beings.

Status. Other living beings can also have meaning because they can be used as a status symbol. This, for example, could be claiming ownership of a particular animal that is rare, unusual or expensive (Hirschman, 1994) or having an elaborate garden that displays power, money, discipline, control or skill (Francis & Hester Jr., 1992). This, for instance, is notably visible in a place like the Palace of Versailles, where the large gardens are maintained and designed to impress. The same could be said of the creation and ownership of bonsai trees which take a lot of time, patience and skill to become what they are. Owning or being associated with certain living beings can elevate or establish someone’s status.

Self-expression and creativity. Other living beings can also have meaning because they can be used as a form of self-expression and creativity. For instance, designing a Japanese-style garden can be a reflection of one’s experiences of travelling and learning about Japan (Francis & Hester Jr., 1992). Other living beings can also be observed in many creative forms of self-expression, such as paintings and other forms of art (Werness, 2006; Farcas et al., 2015). Furthermore, it was found that interacting with other living beings supports the creativity and learning capacities of children, making it easier for them to express themselves (Tim Gill, 2014).

4.4 Performing tasks
Other living beings can perform tasks that humans cannot perform themselves, and/or other living beings can enhance tasks that humans perform. Fermenting food (see figure 6) is an example of something humans cannot do themselves, while this is a natural capacity of some other living beings. Humans use certain bacteria and yeasts in the process of fermentation to make, for example, sourdough (Corsetti & Settanni, 2007), cheese, yoghurt (Widyastuti et al., 2014) and kimchi (Choi et al., 2003). Photosynthesis, the processing of carbon dioxide into oxygen by plant life, is another fundamental example of things humans cannot do that are innate to some other living beings (Jones & Jones, 2014). A different example is that of a guide dog, as they enable humans with visual impairments to safely walk the streets, navigate and do manual tasks (see figure 6).
Humans also rely on other living beings to make tasks easier. For instance, they use animals for draught power (Knight, 2018), transportation (Knight, 2018; Hirschman, 1994) and protection (Maher & Pierpoint, 2011). Oxen can be used as draught power in farming (Knight, 2018), whereas police horses (see figure 6) are used as a means of transportation and protection. Dogs are also known to be kept as guard dogs to protect their owners and the owners’ possessions (Maher & Pierpoint, 2011). Furthermore, other living beings can also be used as a form of entertainment (Knight, 2018) or ornament (Hirschman, 1994). An example of this is having an exotic bird on display (see figure 5).

### 4.5 Source of Material

Other living beings can be a source of material. For instance, animals can be a source of food like meat, milk, eggs (Hirschman, 1994) as can plant life, such as vegetables, herbs and fruits (see figure 7) (van Lier et al., 2017). Animals can also be used as a source of material for clothing (see figure 7) (Knight, 2018). Plants offer natural medicines and can also provide essential ingredients that can be developed into medication (Hartig et al., 2010; van Wyk & Wink, 2017). In addition, plants can also be used to provide materials for crafting things like houses (see figure 7) or furniture. Other living beings can be used as a source of material that humans can directly use or combine and develop into something new.
4.6 Knowledge & skill
Access and exposure to other living beings can lead to knowledge & skill development enabling humans to better understand their own capabilities and develop their capabilities in positive ways (Hartig et al., 2010). For example, gardening is positively associated with healthier eating habits and physical activity (van Lier et al., 2017). By having access to a vegetable garden, humans deepen their understanding about how foods are grown, their wide-ranging varieties, what conditions are needed for their growth and how these conditions effect the quality of the foods’ nutrition. This raises their interest and appreciation for these certain types of foods and makes them more aware of what healthy eating is. Learning how bacteria and yeasts can be used for fermentation enables a person to make certain foods that they would not be able to make otherwise. Living with other living beings enables humans to develop themselves on an fundamental level and enhance and broaden their capabilities.

5. Discussion
To design for the user acceptance of new living artefacts into daily life, a designer first needs to understand how and why humans have been living with other living beings throughout history. To bridge this gap in knowledge a semi-systematic review has been conducted on the research questions ‘Why do humans live with other living beings?’ and a qualitative thematic analysis has been conducted on a body of 60 works around this topic (Section 3). It was found that the existing literature describes six concepts for why humans live with other living beings. These six concepts are the hedonic benefits; Biophilia, Care and Meaning and the utilitarian benefits; Performing tasks, Source of material and Knowledge & skill (Section 4). Based on these six concepts, the following set of 8 design guidelines is proposed to support designing for the user acceptance of living artefacts in daily life:

1. Establish how Biophilia can be experienced by the user with and through the living artefact and what benefits this results in.
2. Establish how care could play a role in the symbiotic relationship between living artefact and user and what benefits this results in.
3. Establish how care for the living artefact could play a role in the social relationship between different users and what benefits this results in.
4. Establish how meaning could be given to or experienced through the living artefact by the user and what benefits this results in.
5. Establish how the living artefact could perform a task that the user themselves cannot do and what benefits this results in.
6. Establish how the living artefact could make a task easier for the user and what benefits this results in.
7. Establish how the living artefact could be a source of material for the user and what benefits this results in.
8. Establish how the living artefact could enable the user to experience knowledge and skill development and what benefits this results in.

These design guidelines are meant as a set of recommendations for designers to take the aspects that could influence the user acceptance of a specific living artefact, according to the six concepts, into account during the design process. They will help to establish what possible benefits a user could experience while in symbiosis with a specific living artefact. Through the process of user testing, the designer can then determine what combination of possible benefits would lead to the highest user acceptance of the living artefact.

It is important to note that although six clear concepts for why humans live with other living beings have been described, this does not mean that these concepts function completely autonomous from each other. Depending on the specific symbiosis between a particular user and a particular living artefact, connections between these concepts and their benefits can be made and could influence each other. This also applies to the design guidelines and the benefits they establish.

In addition, it is important to note the limitations of this research due to the modest body of work used to conduct the semi-systematic review. The available information about why humans live with other living beings is extensive. With this in mind, it was made sure the selected pieces of literature came from a wide range of fields and spoke about a wide variety of symbiosis between humans and other living beings. Furthermore, while examples are given for each concept, it is important to note these examples are far from complete. For each concept, there are many benefits that could be experienced, each with multiple possible examples of how they can be observed in daily life.

Further research could establish if the six concepts encompass all benefits that a person might experience while living in symbiosis with another living being. This could be achieved by conducting additional literature reviews within the different fields that study symbiosis between humans and other living beings. To establish what effect the design guidelines would have on the user acceptance of a living artefact, it would be good to have further research in the form of practical studies that apply and reflect on the above-proposed design guidelines during the design process of living artefacts.

6. Conclusion

Understanding why humans live with other living beings will enable bio-designers to better design for the user acceptance of new living artefacts into daily life. Through conducting a semi-systematic review and a qualitative thematic analysis, it was found that literature describes six concepts for why humans live with other living beings (Section 3). These six concepts are the hedonic benefits; Biophilia, Care and Meaning and the utilitarian benefits; Performing tasks, Source of material and Knowledge & skill (Section 4). The six concepts enable designers to understand what aspects could influence the user acceptance of a new
living artefact in view of the artefacts' aliveness. The six concepts have been developed into eight design guidelines (Section 5) that provide guidance on how these six concepts can be taken into account during the design process of a living artefact. Allowing designers to create living artefacts that people would want to interact and live with and positively contribute to the user acceptance of living artefacts into daily life.

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7. References


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About the Author:

**Simone van den Broek** is an industrial designer, researcher and educator. She works on projects that make people think and encourages them to take action, this with the goal to enable people to improve the quality of their day-to-day lives.

**Alwin de Rooij** conducts (neuro)psychological research to study how creativity and imagination work and how these phenomena can be supported with emerging technologies. This with aim to develop better innovation processes, tools and technologies to support creative professionals in practice.

**Michel van Dartel** is Director of V2_Lab for the Unstable Media and Research Professor at the AVANS Centre of Applied Research for Art, Design and Technology (CARADT).