



HAL
open science

FROM PERCEIVED CREATIVITY TO STATUS QUO BIAS THE CASE OF DIGITAL TWINS IN THE HOME

Maria Mercanti-Guérin

► **To cite this version:**

Maria Mercanti-Guérin. FROM PERCEIVED CREATIVITY TO STATUS QUO BIAS THE CASE OF DIGITAL TWINS IN THE HOME. Des biais décisionnels aux biais algorithmiques, Institut Psychanalyse et Management; Université Paris 1 Panthéon Sorbonne, Nov 2021, Paris, France. hal-03450262

HAL Id: hal-03450262

<https://hal.science/hal-03450262v1>

Submitted on 10 Dec 2021

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



HAL
open science

FROM PERCEIVED CREATIVITY TO STATUS QUO BIAS THE CASE OF DIGITAL TWINS IN THE HOME

Maria Mercanti-Guérin

► **To cite this version:**

Maria Mercanti-Guérin. FROM PERCEIVED CREATIVITY TO STATUS QUO BIAS THE CASE OF DIGITAL TWINS IN THE HOME. Des biais décisionnels aux biais algorithmiques, Institut Psychanalyse et Management; Université Paris 1 Panthéon Sorbonne, Nov 2021, Paris, France. hal-03450262

HAL Id: hal-03450262

<https://hal.archives-ouvertes.fr/hal-03450262>

Submitted on 10 Dec 2021

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

**FROM PERCEIVED CREATIVITY TO *STATUS QUO* BIAS
THE CASE OF DIGITAL TWINS IN THE HOME**

Abstract: Digital twins are a digital representation of the physical world. Among the multiple applications of digital twins, housing is one of the first sectors concerned. The objective of this research is to determine whether interior designs conceived by digital twins are more readable by artificial intelligence than human-designed designs (1) and whether these designs generate more consumer preference (2). Our first experiment shows that AI generates fewer annotation or classification errors when analyzing designs conceived via digital twins. Our second experiment shows that consumers' attitudes are more favorable towards designs conceived by digital twins. Aesthetics and complexity, which are two dimensions of object creativity, are perceived negatively. Only the "novelty" dimension which can be assimilated to modernity explains a strong preference for this type of interior. A discussion on AI as a possible brake on creativity and reinforcement of the *status quo* bias is proposed.

Keywords: digital twins, AI, creativity, *status quo*

FROM PERCEIVED CREATIVITY TO *STATUS QUO* BIAS

THE CASE OF DIGITAL TWINS IN THE HOME

INTRODUCTION

A digital twin is a real-time virtual representation of a product, platform or ecosystem. Based on artificial intelligence (AI), it is increasingly used to model, visualize, predict and provide feedback on the properties of *smart cities*, energy-efficient buildings or the design of eco-friendly products. Its applications are numerous, ranging from archaeology to health. From Notre Dame de Paris, whose reconstruction is being carried out by its digital twin, to the computer modelling of the human body's organs, which enables clinical trials of new molecules, the digital twin is becoming the flagship technology of Industry 4.0. Its fields of intervention range from architecture, mobility and flood management to agriculture, *supply chain* and predictive maintenance. The global digital twins market size is expected to reach \$63.5 billion by 2027, with a market growth rate of 41.7%¹.

Modelling via a digital twin is based on a corpus of images that recreate the real world. This virtual simulation is used in the context of the habitat to model surfaces and interiors. The habitat is increasingly designed to facilitate the management and interventions of embodied AI (robots) or computational AI (algorithms). The objective is to allow them to pick up a cup on a table, to pick up an elderly person who has fallen to the ground (embodied AIs) or to manage consumption and security *data* (computational AIs) of connected habitats.

Interior design is now being profoundly modified by artificial intelligences in search of efficient performance. As the datasets necessary for their operation are based on content already formatted by algorithmic work (easily indexed, therefore from the Web, etc.), the resulting productions often resemble the initial *datasets* (Masure, 2019). From being an analysis tool, AI becomes a generating agent of forms, materials, layout. Nevertheless, this generation relies on the *status quo* since the base material is pre-existing and common. Thus, it is selected for its ability to generate the least possible misidentification. A design chair that breaks the codes and the common representation of the object will be a source of more frequent errors. Its likelihood of being integrated into an interior that is to be digitally twinned will be all the more reduced. It will have to be the subject of a specific *machine learning* so that the AI can identify it as such. From then on, the AI validation of everyday objects could supplant objects privileged by human uses and preferences. It could also eventually kill creativity in favor of identified stereotypes of shapes. It would rely on a *status quo* bias that would lock the user into a reassuring universe that is not subject to change. On the contrary, the relationship between AI and Art is underlined in many researches. The latter show that certain productions resulting from artificial intelligence would present the creative characteristics of a work of art. AI could be both a disruptor and a standardizer of forms.

So we will ask the following question: How are interior images analyzed by Artificial Intelligence? (1) Is there a significant difference between the classification of interior images from designers, home stores and digital twins? (2) Do the images best recognized by AI generate the most *status quo*? (3)

In a first part, we will present the state of the literature on digital twins and the complex links between creativity and artificial intelligence. In the second part, we will present the results of

¹ ResearchandMarkets, Global Digital Twin Market By Type, By Application, By Industry, By Regional Outlook, Industry Analysis Report and Forecast, 2021 - 2027

our research, which consists of two specific research fields. The first field analyzes through two corpora (designer interiors versus interiors designed for digital twins) the mistakes made by artificial intelligence. The second field measures consumer preferences for the two types of interiors. A reflection on the market standardization of forms designed by and for AI is proposed.

DIGITAL TWINS: THE DIGITAL MIRROR OF THE PHYSICAL WORLD

Towards a "twin" world

Digital twins are based on a model of reality. As a result, their operation is based on artificial intelligence, machine learning, data analysis and the Internet of Things. The modeling of reality they propose is based on sensors used in all types of environments from industry 4.0 to the enrichment of connected objects. Digital twins were popularized by Michael Grieves in 2002. A professor at the University of Michigan, Grieves conceptualized the idea of a virtual mirror in a course on *Product Lifecycle Management* (PLM). For Grieves (2005), there is a mirroring or twinning of the physical and virtual models. PLM views the digital twin as a non-static system. The digital twin is a representation of the real but it can modify this real by learning from its errors and failures. The digital twin is therefore permanently connected to its real counterpart. It can intervene in the different phases of a product (creation, manufacturing, exploitation, suppression). Its recent fame is based on emblematic use cases that make digital twins a technology full of promise with multiple applications. For example, NASA has used it in its design of exploration vehicles as well as to replicate the behaviors of *Apollo 13*. Due to technical problems, it was damaged in the middle of the mission when the oxygen tanks exploded. Repairing this damage from nearly 200,000 miles away was made possible by the digital twins. A key part of the oxygen system was physically replicated. All possible solutions were tested on this physical replica. The idea of a virtual replica more adapted to a multitude of tests quickly imposed itself and gave its letters of nobility to the digital twins in the world of aeronautics then industry. The concept of digital twins is, today, multifaceted and covers a quantity of applications. Grieves (2016) proposes a typology of the different types of digital twins which shows the extent and diversity of the possibilities offered (Table 1).

Table 1 - Types and environment of digital twins, adapted from Grieves (2016).

Digital twin type	Specificities
Digital Twin Prototype (DTP)	Includes fully annotated 3D model, bill of materials, processes, services and disposal bill of materials.
Digital Twin Instance (DTI)	Describes a specific physical product to which it remains linked throughout its life cycle.
Aggregation of digital twins	Aggregates all instances of digital twins of a product.

<i>Digital Twin Environment (DTE)</i>	Integrated and multi-domain physical application space allowing the use of digital twins for predictive purposes (prediction of future behaviors and performances of the physical product) or for monitoring and alerting (sensor readings, failure histories...)
---------------------------------------	---

Digital twins extend across different meshes. Used to visualize and evaluate new ideas, they are very useful as lookouts that can warn of possible disasters or malfunctions. At a higher level, the development of digital twin companies prefigures managerial or economic simulations. A digital twin company makes it possible to better conceptualize and visualize product launch strategies, tactical decisions and the establishment of new markets. The last levels concern the ecosystem and orchestration. Managing assets in real time, getting the different twins to communicate with each other, deciding on the basis of feedback illustrate the tendency to see the world as an infinite field of digital replications. The ultimate step is the integration of twins into construction and land-use planning. The best example is British. The UK's National Infrastructure Commission recommended in 2017 the development of a "*National Digital Twin*" to "manage the UK's entire infrastructure system and create a secure, federated digital twin, based on an ecosystem of multiple digital twins developed and driven by different project owners (government agencies, municipalities, etc.)" ². The European Commission is also interested in digital twins through a call for projects entitled *Digital Building Twins*. Construction appears to be the most strategic and lucrative sector for the digital twins industry. A multitude of companies are interested in this sector, including the *Digital Twin Consortium*, made up of some sixty companies including Ansys, Dell, Microsoft, Lendlease, the University of Melbourne and the US Air Force Research Lab. The objective of this consortium is to accelerate the diffusion of digital twins by reinforcing their standardization and thus, their capacity to communicate together.

Digital twins are moving away from their industrial applications and into the field of health (development of a digital twin of a patient before an operation) or *smart cities*. The combination of the two types of twins (health and city) has made it possible to simulate the development of Covid-19 within a city by taking into account multiple factors such as travel, the school system, the age of the inhabitants or the humidity level. The nuclear industry and cyber security have also been disrupted in their *processes* by the use of digital twins (Mittal, 2020).

Exploiting human weaknesses

Digital twins are increasingly seen as revealing human weaknesses and our limitations in conceptualizing and remembering the object. Grieves (2005) points out that digital twins have been around for a very long time. The human brain is capable of visualizing an object, but this visualization is necessarily imperfect. Furthermore, the physical representation of the object in physical form, first as sketches and blueprints, and then as expensive prototypes, allowed for very limited sharing and understanding of form and behaviour. Finally, what Grieves (2005)

² Nine guiding principles have been defined (known as the *Gemini principles*) by the *Center for Digital Built Britain*. These principles focus on the positive aspect of digital twins in terms of product (public good, value creation, vision), trust (security, openness, quality) and function (federation, preservation, evolution). The *Institute for Manufacturing (IfM)* building is used as a pilot project (source <https://lartec.etsmtl.ca/index.php/fr/notre-blog/item/41-digital-twins>).

calls the fidelity and permanence of our human memory leaves much to be desired. He notes that "our ability to create and retain detailed information in our memories over a long period of time is not very good. Even for simple objects, asking us to accurately visualize their shape is a task that many struggle to accomplish accurately. Ask most of us to manipulate complex shapes in space, and the results would be hopelessly inadequate" (Grieves, 2005, p. 5). The strength of digital twins is that they can transform any object into data that allows for exact replication.

Digital twins: the ultimate AI

However, according to Trauer and Schweigert-Recksiek (2020), a digital twin is not only defined by the data it incorporates. The digital twin also includes algorithms, mainly simulations (Kuhn, 2017; Boschert and Rosen, 2016). Therefore, a digital twin is often described as the top-level simulation, as it includes real use phase data (Schluse and Rossmann, 2016). The digital twin could correspond to the ultimate phase of artificial intelligence based on a high level of learning (*deep learning*). According to Moya (2020), a digital twin's characteristic is to replicate an object based on constantly changing data. It therefore incorporates any change in the material or structure almost immediately. This concept is closely related to that of dynamic data-driven application systems (DDDAS). 3,4,5 F. Darema (2004), developer of DDDAS, highlighted the symbiotic collaboration between data and simulation (Moya, 2020). This symbiosis significantly improves the accuracy of predictive models based on digital twins. It also increases its learning capabilities. Fuller *et al.* (2020) listed, based on several dozen experiments, all the technologies associated with digital twins. Regarding AI, the authors note that digital twins are concerned with machine learning (1) (subsection of AI) used to create programs based on algorithms that collect and analyze data autonomously, supervised learning (2) (subsection of AI) that learn from training data and then receive test data to see how well the system minimizes its initial errors. To these two types of learning, we can add unsupervised learning (3). Unsupervised learning algorithms learn using their own categorization methods (*clustering*) instead of relying on user feedback (Lin *et al.*, 2020). They cluster unlabeled datasets, with some hidden ones not explicitly identifiable. The last type of learning (deep learning) (4) has algorithms learning unstructured and unlabeled data using complex neural networks (Modi, 2018). All these learning modes and corresponding algorithms are present in digital twins.

Digital twins and product design: *status quo* versus creativity?

Digital twin developers promise "no-fail" launches for many everyday products. It is possible that digital twins will emerge as a new path of study in which design, use and adoption are perfectly aligned. For proponents of digital twins, "The biggest difference between a digital twin interface and simple 3D product modeling software is that by developing designs with digital twins, you are able to immediately see how your product design will interact with the environment and predict customer usage. This will ensure that you are on the right track to develop a product that is 100% environmentally friendly, user-friendly and built to last³. This philosophy is not at odds with the research being conducted in the field of design. One of the most recognized trends in design research links creativity and adaptation to needs. Besemer and O'Quin's (1986) scale for measuring perceived creativity in object design has given rise to a broader reflection on the notion of perceived useful creativity, creativity made for the user in the field of housing. This scale, known as the *Creative Product Semantic Scale* (CPSS

³ <https://www.challenge.org/insights/digital-twin-in-design/>

matrix), is an interesting first attempt to evaluate creativity by the non-expert consumer. The identified dimensions of the scale are novelty, resolution, and the "synthesis and elaboration" dimension. Taking into account other works in related fields allows us to enrich this measure (Haberland and Dacin, 1992; Mercanti-Guérin, 2008) and to synthesize it along three directions. A creative design must be perceived as novel (1), aesthetic (2), and have some degree of complexity (3) (design to solve a problem or maximize the utility of an object). The question arises as to how digital twins fit into this highly aesthetic and utilitarian view of objects made by and for humans. According to Besemer and O'Quin (1999), perceived creativity cannot be abstracted from a strong aesthetic dimension because aesthetics would convey *insights* related to the quality and the precious character of the object. Furthermore, the complexity dimension, which includes an evaluation by the consumer of the ingenious nature of a product, implies a relatively gradual handling. A product considered too simple loses its appeal. On the other hand, if we take the example of *the Institute for Manufacturing*⁴, which is a pioneer in the use of digital twins for housing, the invariants it puts forward in the design of manufactured products do not fit well with the creative vision of designers and manufacturers who use the CPSS matrix. The use of *Big Data* (massive data in all models), the importance of product standardization, the desire for interoperability of design models propose another vision of the habitat. Nevertheless, the will to stand out and "disrupt forms and functions" still exists. In this sense, their strategy could increase the *status quo* bias already visible in consumer choices. If we take up Kim and Lee's (2016) model of the *status quo*, the costs of change influence perceived value and resistance to change. Creative products must therefore deliver a superior user experience. Yet, the extreme standardization of twin products could significantly decrease the uncertainty or transition costs for the consumer and have, as a paradoxical effect, an increase in the perceived value of this type of product.

This leads us to wonder about the growing influence of AI on our interiors. The last place of private life, the interior is, at the same time, a space for relaxation, protection, family life and privacy but also a place of representation and social categorization. It is also a revealer of our tastes, lifestyles and culture (Tapie, 2018). However, this sacred space has been the object, for some years, of a digital offensive to take possession of it (Santos and Toni, 2021). Proof of this is the development of *smart homes* or connected houses (Ricquebourt *et al.*, 2006) or the use of personal assistants (Abdallah *et al.*, 2020) within the home. Everyday objects and the layout of our interiors represent a new field of intervention for digital technology. Its involvement in their design is due to the fact that an interior designed by an AI allows it to evolve more easily. In addition, the rapidly expanding⁵ trade in decorative objects (60 billion euros in 2020 in France alone) represents an extremely interesting field of experimentation for digital twins since it combines the object with an environment with multiple constraints. Working on digital twins for interior design has an influence on the design of products, housing and space planning. The concept of *Home Design* and its 3D applications are precursors of digital twins that are starting to be used by brands like Habitat or Ikea.

RESEARCH DESIGN AND RESULTS

Therefore, we conducted two experiments to evaluate the influence of digital twins on interior designs both in terms of product design and matching consumer preferences. We conducted an experiment using an artificial intelligence tool, *Google Cloud Vision* (1) and an experiment based on a conceptual research model based on the literature of perceived advertising creativity (2).

⁴ https://www.ifm.eng.cam.ac.uk/uploads/IfM_Review/Issue6/IFMR_6.pdf

⁵ <https://www.forbes.fr/business/marche-du-meuble-en-2021-le-boom-digital/>

Google Cloud Vision is based on an API that has pre-trained *machine learning* models. This tool assigns labels to images and quickly sorts them into millions of predefined categories. It can detect objects and faces, read printed or handwritten text, and integrate metadata into the image catalog.

Research design

Experiment 1, how are interior images analyzed by Artificial Intelligence? Is there a significant difference between the classification of interior images from designers, decoration stores and digital twins?

We submitted to the *Google Cloud Vision* Artificial Intelligence tool three types of images from three different corpora.

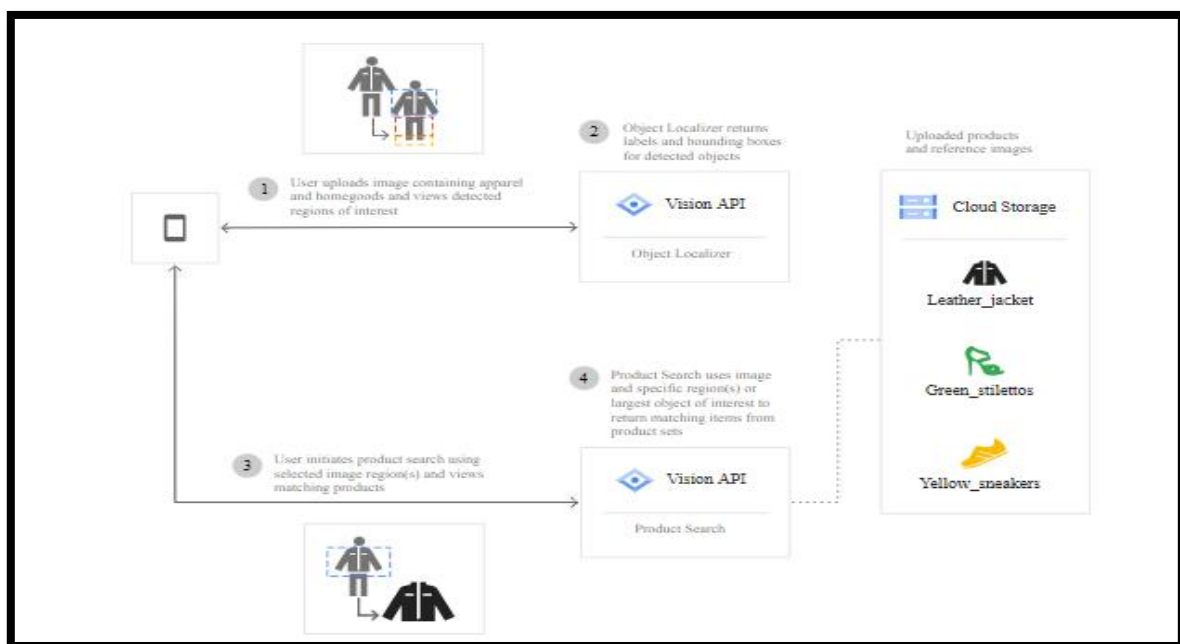
Corpus 1: a series of interior images by designers who have won international awards for their creativity (Antalis Award, Ideat, Edida)

Corpus 2: a series of indoor images created by Geomagical Labs, an AI imaging startup partnered with Ikea

Corpus 3: a series of interior images designed by AI Habitat Facebook, an *open source* simulator for training robots in virtual reality environments and for designing digital twins.

The operation of Google Cloud Vision is detailed in the following figure (Figure 1)

Figure 1 - How Google Cloud Vision works



The table in the appendix summarizes all three corpora studied. 48 types of design were selected (Appendix 1). They can be divided into two groups: a highly creative group with award-winning interior designs and a group designed by or for digital twins.

A typology of errors observed in artificial intelligence tools has been drawn from the literature focusing on their detection and qualification (Nazari et al., 2018; Xu et al., 2019). The types of errors identified are as follows:

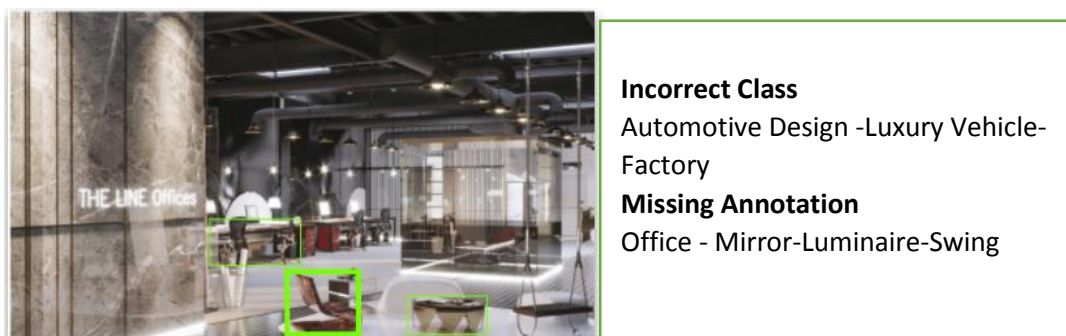
- ✓ Incorrect class: An object is classified incorrectly, for example, a vehicle is labeled as a pedestrian.
- ✓ Incorrect attribute: The state of an object is not described correctly, e.g. a moving car is labelled as parked.
- ✓ Missing annotation : An object is not annotated when it should be.
- ✓ Redundant annotation: An object is annotated when it should not be.

The two following diagrams show the types of errors observed for a "La Redoute" interior and for an interior from the corpus.

Figure 2 - Example of the difficulty of authenticating a chair of the brand "La Redoute" by the artificial intelligence tool "Google Cloud Vision".



Figure 3 - Type of error found on an interior of the corpus



The Line Office, corpus Antalis Award

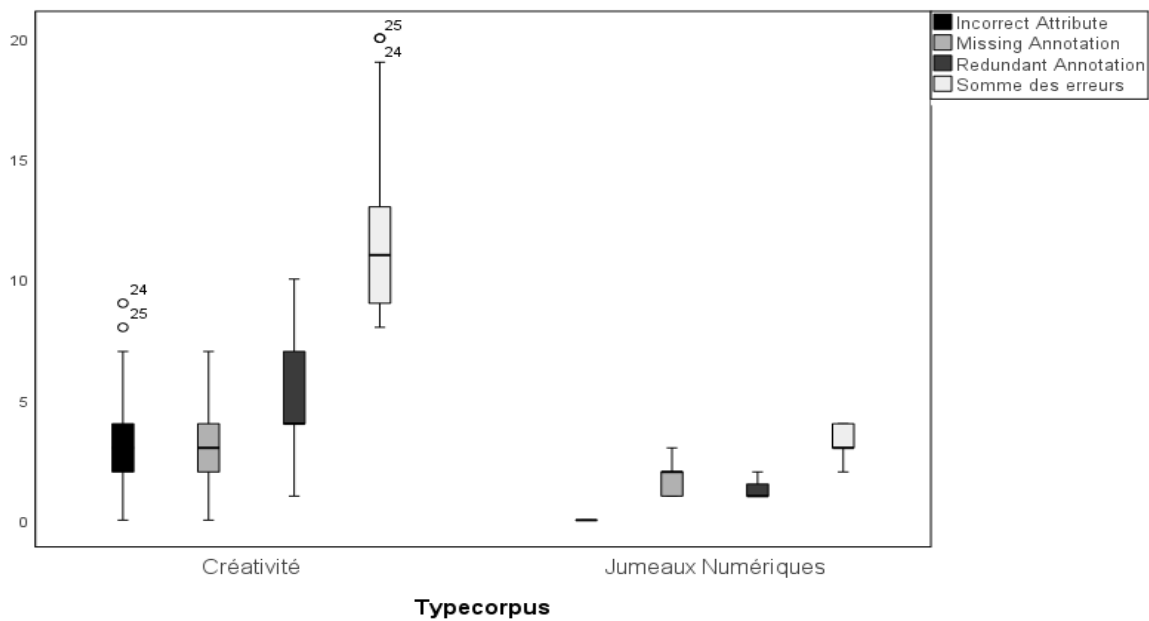
Results

The multivariate analysis performed on these data shows a significant difference between the errors depending on the corpora studied except for the error type "Missing Annotation" for which the difference is not significant. Thus, the type of corpus has a statistically significant

effect on the error "Incorrect Attribute" ($F(4, 27) = 10.91$; $p < .0005$; partial $\eta^2 = .62$) and "Redundant Annotation" ($F(4, 27) = 19.02$; $p < .0005$; partial $\eta^2 = .73$). The effect was also significant on the sum of errors ($F(4, 27) = 21.37$; $p < .0005$; partial $\eta^2 = .76$). In contrast, corpus type has no significant effect on the "Missing Annotation" error ($F(4, 27) = 1.65$; $p > .0190$; partial $\eta^2 = .197$).

The different types of corpora classified in two groups, a "creativity" group (Antalis-Ideat-Edida corpus) and a "digital twins" group show a higher number of errors in the "creativity" group with a stronger dispersion which illustrates the difficulties of the AI to analyze certain designs (figure 7).

Figure 4 - Types of error according to the corpus



Experiment 2, do the images best recognized by the AI generate the most status quo?

210 individuals were subjected to a questionnaire based on the Mercanti-Guérin creativity scale (2008). The test material was taken from the two types of corpus used in Experiment 1. The model is composed of the three dimensions of perceived creativity (novelty, aesthetics, complexity) and their respective influence on preference (favorable or unfavorable attitude to the experimental designs). The chosen experimental design includes 6 design types (three from the Antalis-Ideat-Edida corpus, three from the digital twins developed by AI Ikea Facebook).

The table shows that the independent variables statistically significantly predict the dependent variable, $F(3, 198) = 506$, $p < 0.0005$ (i.e. the regression model fits the data well). Furthermore, the R^2 or variance explained by the model is very high (.885) shows the influence of perceived creativity on attitude towards design. Multiple regression was performed to predict attitude from perceived novelty, aesthetics and complexity. These variables statistically significantly predicted attitude towards design. Nevertheless, it was found that the higher the perceived complexity of the design, the lower the attitude towards the design. Too much complexity (too many objects, too many colours, busy design) has a

negative effect on attitude. The same applies, to a lesser extent, to aesthetics. Too much aesthetics would prevent people from projecting themselves into an interior adapted to their needs. The novelty dimension (perceived modernity) appears to be reassuring and more attractive, with a positive influence on attitude.

Table 2 - Influence of creativity dimensions on attitude towards design

Model		Non-standardized coefficients		Standardized coefficients	t	Sig.
		B	Standard error	Beta		
1	(Constant)	3,690	,413		8,946	,000
	New	,573	,044	,468	13,139	,000
	Aesthetics	-,202	,060	-,085	-3,342	,001
	Complexity	-,457	,030	-,539	-15,492	,000

a. Dependent variable: Attitude

Isolating the type of design (creative versus digital twins), it appears that the perception of aesthetics negatively influences attitude when only the interiors imagined by the designers are submitted ($t=-4.5$, $p=0.000$). When the sample is subjected to the "digital twins" corpus, all three dimensions have an influence on attitude. Novelty has a positive influence, aesthetics and complexity a negative one.

Furthermore, the attitude towards the proposed design is significantly more favourable towards the digital twins than towards the designers' creations ($t(171) = 33$, $p = 0.000$).

If we analyse these results in the light of the literature on *status quo bias*, the perceived complexity of a design may lead the individual to resist change because the costs of adapting to a complex interior or object are judged to be too great in relation to the perceived benefit. Aesthetics that are considered too disruptive will instead affect transition costs (getting used to new shapes, materials, colours). The perceived novelty observed in the designs proposed by the digital twins does not encourage the status quo but rather a moderate change. The favourable attitude towards this type of design shows that the interiors created by the digital twins are seen as practical and do not evoke a rejection of change for the consumer. However, this change is moderate. Items measuring novelty are representative of a low level of creativity. A commercially oriented AI does not represent a brake on creativity, up to a certain point. This moderate creativity may lead the consumer to buy the sister products without really leaving a certain comfort zone. A very favourable attitude towards this type of interior may be a sign of resistance to change in the long run: no longer consuming products that are disruptive both in use (complexity) and in form (aesthetics). A strong attachment to these products based on a pleasant user experience may lock them into a standardized filter bubble in terms of choices and preferences.

DISCUSSION

We will organize our discussion into two parts. The first part focuses on the biases inherent in the production of digital twins. The second part presents some ideas for improvement that could mitigate these biases.

Status quo bias as a guarantee of commercial success

The results of our research show that the more creative the design is considered by the design profession or interior decorators, the less readable it is by AI. Errors in object categorization or redundancy can be a problem for this type of design. Indeed, a creative design becomes very difficult to test both in terms of its acceptance by the consumer and its integration into commercial catalogues or *showrooms*. A creative design is, in a way, eliminated from the industrial process that affects the decoration market. AI has a poor grasp of disruptive forms and cannot integrate them into the manufacturing *process*, but also into the creative process (digital libraries used by architects for example, 3D software). Regarding our second experiment, the majority of consumers prefer interiors designed by digital twins. This may reinforce the *status quo* bias. Evolving in environments that offer relatively few invariants of form, colour or material can educate consumers and reduce their tolerance to complexity or to an overly disruptive aesthetic. These results confirm what has already been observed concerning search engines. Biased algorithms give priority to popularity by erasing differences, nuances and micro-trends. This crushing of the variety of preferences is visible on the Web. As Lerman, and Hogg (2014) point out, users tend to interact more with the top results and pay little attention to those further down the list. As a result, the results at the top of the list will become increasingly popular due to the biased interaction and placement of results by these algorithms. The structure of e-commerce that relies on recommendations and specific search engines follows the same logic.

Nevertheless, a systematically standardized business proposition can have two effects. The first effect is an adoption effect not of the innovation but of the *status quo* by individuals with strong resistance to change. The second effect can lead to strong resistance from certain consumers. This phenomenon of resistance already observed in other areas of consumption (food, attitude towards advertising...) could be reinforced in housing or in other sectors affected by the standardization imposed by AI.

The making of the algorithm: a succession of steps subject to bias

More generally, this research questions the fabrication of algorithms. In the context of digital twins, the process of making the algorithm relies on selected developers. If we take the case of "Habitat Challenge", the teams constituting the challenge are almost exclusively male, competing among themselves and working only in English. These characteristics lead to a number of biases mentioned in the literature.

Population Bias. Population bias occurs when the statistics, demographics, user characteristics are different in the user population versus the original target population (Olteanu et al, 2019). In our case, the population of early users or testers of images embedded in image libraries is inherently different from the user or consumer of this type of design. The population bias creates unrepresentative data.

Social Bias. Social bias occurs when the actions of others affect our judgment (Ricardo, 2018). If we take the example of "Habitat Challenge", the forums, the workshop sessions that allow teams to progress by asking questions anonymously to experts show that the selection process is not only based on a performance analysis based on the capabilities of the competing algorithms. All these social interactions can generate popularity bias between teams.

Historical bias. Historical bias has been highlighted in image searches. In 2018, a search for images of CEOs predominantly suggested men. This bias reinforces the prejudice that a woman is rarely the head of a company (Suresh and Guttag, 2019). Similarly, a search for images in 2021 of current interiors predominantly refers to furniture marketed by brands that

are dominant on the web in terms of commercial presence (e-shop, natural referencing). The image libraries are modelled on these e-commerce trends, which may not be the same in 3 years and which are different from past preferences. This bias raises questions about the ability of AI to integrate change. In the context of a gradual feminization of management bodies, search engines will always have a gap with reality. Nevertheless, ethical consideration of gender bias will eventually generate engine responses more in line with reality. This is far from the case with commercial products where it is possible to encounter several types of bias typically generated by the digital interface and, in particular, presentation and ranking bias (the more content is seen, the more it is clicked and the more it is seen) (Lerman and Hogg, 2014).

Ethical design or ethics by design

These elements raise questions about the capacity of a sector (in our case interior design) to make the most of artificial intelligence both in terms of understanding uses and detecting emerging preferences. The literature on user interfaces and the ethics *by design* of these interfaces is extremely vast. More rare is the study of these interfaces in the design sector. In contrast, the notion of ethical design is a concern when considering the effects of AI in the construction sector. These concerns are driven by the expansion of *smart cities* and the management of mobility through AI. Living spaces are becoming privileged areas for artificial intelligence. Questions about the effects of AI on this sector are mainly focused on the processing and respect of personal data. Rare studies focus on the improvement of design processes and design management practices. The concepts of *lean management*, ethical user interfaces impose the notions of regular iteration at each stage of the projects. Pikas *et al* (2020) synthesise an ethical approach to design by proposing a model where the notions of flow and value analysis are essential. They point out that design had also been mistakenly viewed as a solely technical activity. In order to balance the "technical" vision of design, it is urgent to reflect on a new model that integrates the technical and social dimensions. The authors even propose a kind of backward step where at each stage the human being is questioned and his requirements taken into account. "*Poor customer and user engagement, poor requirements analysis, lack of a systematic study of alternatives and shortcomings in design quality indicate deficiencies in the value vision. Problems in planning and controlling the design process require the use of conventional project management methods*" (p. 11).

Therefore, design models could be articulated following the following steps as described by Pikas *et al.* (2020). This model would integrate AI in a perspective of permanent dialogue between designers and users. It would intervene at the following stages: implementation, solution generation, transformation, interpretation. Iteration loops would be restarted at each element of the solution construction. The dialogue "design proposed by AI - feedback from users" would be permanent and would allow to reduce in an iterative way the possible biases. A second stream of research advocates for better ethics training for designers/developers. Gray *et al* (2018) have studied the "dark side of UX (user experience) design". They question the interference of the interface which includes, but is not limited to, pre-selection, playing with emotion, false hierarchy. Pre-selection is usually manifested as a default choice that the product owner wants the user to choose. Playing with emotion includes any use of language, style, color, or other similar elements to evoke an emotion. A false hierarchy gives one or more options visual or interactive precedence over others, especially when the elements should be in parallel rather than hierarchical. This convinces the user to make a selection that they feel is the only or best option. All of these manipulations can be generated by an AI programmed to generate default choices that give the user an impression of free will when it is not. The authors advocate a real revolution in the training of designers. They wish to link

the design activity to fundamental philosophical commitments. For them, this approach values the humanity and character of the designer as essential to ethically responsible design activity. They insist, in particular, on the fact that these manipulations affect the most fragile populations who cannot perceive the techniques of interface manipulation. It would therefore be possible, in the long term, to see AI deciding for the least protected, while the upper classes would escape its influence through their critical capacity.

CONCLUSION

To conclude, the purposes of AI need to be better considered in determining cognitive biases. In the context of our research, an AI designed to sell may promote a moderate form of creativity. In this sense, the integration of AI into product design does not change the mechanics observed in the literature regarding perceived creativity. Thus, too much creativity may undermine consumer adherence to the product. Regarding the AI designed for digital twins, it does not appear as a reassuring AI offering a familiar and practical living environment. Nor does it appear as a threatening AI that locks the individual in a sea of algorithmic stereotypes. It is seen as a bearer of modernity, giving the desire to change one's interior "to a certain extent". The question of whether its perfect adaptation to image recognition practiced by search engines such as Google and its e-commerce tool Google Shopping could lead the digital twins to impose their standard in the field remains to be verified.

The progressive encoding of all human experiences into "food" for AI is diverted from its primary purpose. AI is no longer at the service of humans in the sense of Asimov, but rearranges the world so that it can evolve in a simpler and more efficient way. To design these digital twins, AI reproduces virtual spaces according to thesauri of images that are easily indexed and tagged. This reproduction of a statistically distorted reality questions the ability of new forms or objects to fit into the integrative and normative world of AI. As Kim and Lee (2016) point out, advances in information technology have demolished industry silos and given momentum to technological convergence. Platforms and interface standards are becoming the new routes to industrial standardization. This standardization is reinforced by the network effect. The taste of the many is forged by AI, which needs this mass effect to create positive feedback loops that generate economies of scale on the demand side. This ongoing phenomenon of platform envelopment underscores the importance of understanding behavioral factors as consumers often resist using a new user interface. *Status quo* bias feeds on similar experiences in other types of environments. A highly standardized user interface that is becoming equally prevalent in the design of video games, mobile usage, and soon in the choice of one's furnishings foreshadows what Kim and Lee (2016) call "the extension of lock-in effects to user interfaces in a cross-platform environment" and ultimately a world of accepted or even desired *status quo*. Furthermore, it is worth distinguishing between two types of bias: production biases that are generated by algorithm designers and what we will call adoption biases that lead users of "biased" products to generate biases themselves that directly impact their behaviors. This self-perpetuation of biases throughout the AI value chain (from designer to user) should lead us to reconsider the learning and training processes, not only with an ethical aim (Besse et al., 2017), but also, of behavior modification. This *nudge* based on an AI made to combat our cognitive biases and, not propagate them, represents a major challenge for artificial intelligence. Mirsch et al (2017), in introducing the notion of digital *nudge*, insist on the definition of objectives as an indispensable first step to the adoption of virtuous behaviors thanks to digital technology. At a time when training virtuous AIs or ethical AIs *by design* is increasingly possible, the persistence of significant biases

questions the designers' aims, especially, when the latter have a purely commercial vision of artificial intelligence.

BIBLIOGRAPHIC REFERENCES

- Abdallah, N. H., Affes, E., Bouslimani, Y., Ghribi, M., Kaddouri, A., & Ghariani, M. (2020, May). Smart Assistant Robot for Smart Home Management. In *2020 1st International Conference on Communications, Control Systems and Signal Processing (CCSSP)* (pp. 317-321). IEEE.
- Besemer, S. P. and K. O'Quin (1986), Analyzing creative products: Refinement and test of a judging instrument, *Journal of Creative Behavior*, 20, 2, 115-126.
- Besse P., Castets-Renard C., Garivier A. (2017). Loyalty of Algorithmic Decisions, Contribution to the CNIL's "Ethics and Digital" Debate.
- Boschert, S. and Rosen, R. (2016), "Digital Twin-The Simulation Aspect", in Hehenberger, P. and Bradley, D. (Eds.), *Mechatronic futures: Challenges and solutions for mechatronic systems and their designers* , Peter Hehenberger, David Bradley, editors, Springer, Switzerland, 59-74. https://doi.org/10.1007/978-3-319-32156-1_5
- Darema F. (2005), Grid Computing and Beyond: The Context of Dynamic Data Driven Applications Systems. *Proceedings of the IEEE*, 93(3), 692-697.
- Fuller, A., Fan, Z., Day, C., & Barlow, C. (2020). Digital twin: Enabling technologies, challenges and open research. *IEEE access*, 8, 108952-108971.
- Gray, C. M., Kou, Y., Battles, B., Hoggatt, J., & Toombs, A. L. (2018, April). The dark (patterns) side of UX design. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems* (pp. 1-14).
- Grieves M. W. (2005). Product lifecycle management: the new paradigm for enterprises. *International Journal of Product Development*, 2(1-2), 71-84.
- Grieves, M. (2016). Origins of the digital twin concept. *Florida Institute of Technology*.
- Haberland, G.S. and P.A. Dacin (1992), The Development of a Measure to assess Viewers' Judgments of the Creativity of an Advertisement: a Preliminary Study, *Advances in Consumer Research*, 19, 817-825.
- Kim, D.-H. and Lee, H. (2016) Effects of user experience on user resistance to change to the voice user interface of an in-vehicle infotainment system: Implications for platform and standards competition. *International Journal of Information Management*, 36(4), 653-667.
- Kuhn, T. (2017). Digitaler Zwilling. *Informatik-Spektrum*, 40(5), 440-444.
- Lerman, K., & Hogg, T. (2014). Leveraging position bias to improve peer recommendation. *PloS one*, 9(6), e98914.
- Lin, H. Y., Dai, J. M., Wu, L. T., & Chen, L. Q. (2020). A vision-based driver assistance system with forward collision and overtaking detection. *Sensors*, 20(18), 5139.
- Masure, A. (2019). Resisting black boxes. Design and artificial intelligences. *Cites* (4), 31-46.
- Maudet, N., Philizot, V., & Zara, S. (2021). What do AI images do?
- Mercanti-Guérin, M. (2008). Consumer perception of a creative ad: construction and validation of a measurement scale. *Recherche et Applications en Marketing* (French Edition), 23(4), 97-119.
- Mirsch, T., Lehrer, C., & Jung, R. (2017). Digital nudging: Altering user behavior in digital environments. *Proceedings der 13. Internationalen Tagung Wirtschaftsinformatik (WI 2017)*, 634-648.
- Mirsch, T., Lehrer, C., & Jung, R. (2017). Digital nudging: Altering user behavior in digital environments. *Proceedings der 13. Internationalen Tagung Wirtschaftsinformatik (WI 2017)*, 634-648.

- Mittal, H. (2020). Digital Twin: an Overview, *CSI Communications*.
- Modi, A. S. (2018, June). Review article on deep learning approaches. In 2018 *Second International Conference on Intelligent Computing and Control Systems (ICICCS)*, 1635-1639.
- Moya, B., Badías, A., Alfaro, I., Chinesta, F., & Cueto, E. (2020). Digital twins that learn and correct themselves. *International Journal for Numerical Methods in Engineering*.
- Mulfari, D., Celesti, A., Fazio, M., Villari, M., & Puliafito, A. (2016, June). Using Google Cloud Vision in assistive technology scenarios. In *2016 IEEE symposium on computers and communication (ISCC)*, 214-219.
- Nazari, Z., Nazari, M., Danish, M. S. S., and Kang, D. (2018). *Evaluation of class noise impact on performance of machine learning algorithms*.
- Olteanu, A., Castillo, C., Diaz, F., & Kıcıman, E. (2019). Social data: Biases, methodological pitfalls, and ethical boundaries. *Frontiers in Big Data*, 2, 13.
- Pikas, E., Koskela, L., & Seppänen, O. (2020). Improving building design processes and design management practices: a case study. *Sustainability*, 12(3), 911.
- Ricardo, B. Y. (2018). "Bias on the Web. *Communications of the ACM*, 61(6), 54-61.
- Ricquebourg, V., Menga, D., Durand, D., Marhic, B., Delahoche, L., & Loge, C. (2006, December). The smart home concept: our immediate future. In *2006 1st IEEE international conference on e-learning in industrial electronics* (pp. 23-28). IEEE.
- Santos, M., & Toni, F. (2021). Artificial intelligence-empowered technology in the home. In *The Home in the Digital Age* (pp. 38-55). Routledge.
- Schluse, M. and Rossmann, J. (2016), From simulation to experimentable digital twins: Simulation-based development and operation of complex technical systems, in *ISSE 2016: 2016 International Symposium on Systems Engineering*, Edinburgh, Scotland, George Hotel, October 3-5, 2016 proceedings papers, Edinburgh, United Kingdom, 10/3/2016 - 10/5/2016, IEEE, Piscataway, NJ, 1-6.
- Suresh, H., & Gutttag, J. V. (2019). A framework for understanding unintended consequences of machine learning. arXiv preprint arXiv:1901.10002, 2.
- Tapie, G. (2018). Sociology of space: models of interpretation. *Sociologias*, 20, 370-391.
- Trauer, J., Schweigert-Recksiek, S., Engel, C., Spreitzer, K., & Zimmermann, M. (2020, May). What is a Digital Twin -Definitions and Insights from an Industrial Case Study in Technical Product Development. In *Proceedings of the Design Society: DESIGN Conference* (Vol. 1, 757-766). Cambridge University Press.
- Xu, M., Bai, Y., Ghanem, B., et al. (2019). *Missing labels in object detection*.

Appendix 1 - Summary of the corpora by type of design and error

	Design type	Type of error			
		Incorrect Class	Incorrect Attribute	Missing Annotation	Redundant Annotation
Antalis Award	BOUTIQUE HOTEL MARIËNHAGE	0	3	3	4
	CO-WORKING LE SEVEN	0	2	3	4
	HOTEL IBIS STYLES	0	3	6	4
	ITALIAN MOOD APARTMENT	0	2	3	5
	RESTAURANT LE BOVEM	1	4	2	4
	JAMES BOND APARTMENT	1	3	0	4
	HOTEL MERCURE MALAKOFF	1	4	4	1
	JUNGLE BATHROOM EXOTIC	1	3	2	3
	UNDER THE SEA	1	3	4	3
	THE BEACH AT WORK	1	2	7	3
	TIMELESS	1	6	4	6
	OGÓLNOPOLSKA SIEC KIN	1	4	2	7
	"CASTLE OF LIGHT! A RAY OF LIGHT TO THOSE WITH VISION IMPAIRMENTS!"	1	7	2	3
	NATURAL GREEN CREATIVE SPACES, FOR MOËT AND CHANDON ROYAL ASCOT	1	2	2	7
	THE EDGE CAFE	1	3	3	2
	RESTAURANT "CHEZ MOI	0	1	4	4
	BOWLING	0	0	4	4
	APARTHOTEL ADAGIO PARIS MONTROUGE	0	1	3	5
IDEAT	FOB 2021	1	6	7	5

	CHAIR WIRED	0	0	6	6
	LADY GALALA	0	0	0	10
	DISDEROT LAMP	0	0	0	8
EDIDA	BORGHI by GUMDESIGN for ANTONIO LUPI - BASHROOM	1	6	1	8
	INTERSECTION KITCHEN	1	9	1	9
	WALL COVERING- WALL PAPER	1	8	1	10
GEOMAGICAL LABS	CABINETRY FOR IKEA	0	0	3	1
	LIVING ROOM FOR IKEA	0	0	1	1
AI HABITAT FACEBOOK	IKEA BOOK BOXES	0	0	1	2
	IKEA KITCHEN	0	0	2	1
	IKEA HALL	0	0	2	2
	IKEA KITCHEN 2	1	0	1	1
	IKEA STUDIO	1	0	2	1
	IKEA KITCHEN 3	0	0	2	1
	IKEA HALL 2	0	0	3	2
	IKEA KITCHEN 4	1	0	3	1
	IKEA STUDIO 2	1	0	2	2
	IKEA KITCHEN	0	0	2	1
	IKEA HALL 3	0	0	1	2
	IKEA KITCHEN 5	1	0	1	2
	IKEA STUDIO 3	1	0	2	1
	IKEA KITCHEN 6	0	0	2	1
	IKEA HALL 4	0	0	1	2
	IKEA KITCHEN 7	1	0	2	1
	IKEA STUDIO 4	1	0	1	2