

Article

Social Robots, Brain Machine Interfaces and Neuro/Cognitive Enhancers: Three Emerging Science and Technology Products through the Lens of Technology Acceptance Theories, Models and Frameworks

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Abstract: Social robotics, brain machine interfaces and neuro and cognitive enhancement products are three emerging science and technology products with wide-reaching impact for disabled and non-disabled people. Acceptance of ideas and products depend on multiple parameters and many models have been developed to predict product acceptance. We investigated which frequently employed technology acceptance models (consumer theory, innovation diffusion model, theory of reasoned action, theory of planned behaviour, social cognitive theory, self-determination theory, technology of acceptance model, Unified Theory of Acceptance and Use of Technology UTAUT and UTAUT2) are employed in the social robotics, brain machine interfaces and neuro and cognitive enhancement product literature and which of the core measures used in the technology acceptance models are implicit or explicit engaged with in the literature.

Keywords: social robotics; assistive robotics; brain machine interface; brain computer interface; neuroprosthetics; neuroenhancement; cognitive enhancement; technology acceptance model; disabled people; people with disabilities; therapeutics; therapeutic enhancements

1. Introduction

Social robotics is a rapidly growing field which offers innovative and ever-more complex technologies for use within a range of sectors including education, healthcare and service [1–16]. Brain machine interfaces (BMI), another evolving field, has future prospects with helping disabled people, assisting military soldiers, and for gaming purposes [17–32]. The technology involves the interaction of human thought with an external device (e.g., robot, robotic limb, smart wheelchair, communication device) which translates and executes an action of the user's intent [33,34]. This can be achieved through invasive (surgical) or non-invasive (non-surgical) procedures. The clinical viability of BMI technology for disabled people is determined by a cost (surgical risks, financial accessibility, reliability) benefit (improvement of quality of life) analysis [35–38]. BMI technology can be used by disabled people to gain functions seen as species-typical [39–41] but at the same time also gives disabled people beyond species-typical abilities (therapeutic enhancement). At the same time BMI could also be used by non-disabled people by the “healthy” to gain the beyond species-typical abilities (non-therapeutic enhancement). Finally, there is an increasing discussion around human enhancement beyond the normal or species-typical [42–68], and particularly around neuro and cognitive enhancement of the “healthy” [69–76]. The three products covered in this paper belong to a new category of therapeutic products—therapeutic products that can lead to therapeutic and non-therapeutic enhancements [43,60,61,77–79].

Acceptance of ideas and products whether sold as consumables or therapeutics depends on several parameters. As to consumer goods, parameters include: the perception of its utility, quality, and value [80], risk perceptions and consumer concerns [81] and the weighing of risks and benefits [82]. For example, Frewer concludes that “the most important determinant of consumer acceptance of genetic engineering in food technology is likely to be perceptions of benefit resulting from application of the technology” [83]. According to Greenhalgh *et al.* and others, over 1,000 papers on the diffusion, spread and sustainability of innovation in health service organisations exist [84].

Many models have been developed to predict product acceptance. We will use the following models to focus on the user acceptance of social robotics, BMI, and neuro and cognitive enhancements: consumer theory [85–88]; innovation diffusion theory (IDT) [89–92]; theory of reasoned action (TRA) [93–99]; theory of planned behaviour (TPB) [100–103]; social cognitive theory (SCT) [104–108]; self-determination theory (SDT) [109–117]; technology of acceptance model (TAM) [118–126]; Unified Theory of Acceptance and Use of Technology (UTAUT) [127–137]; UTAUT2 [138]; model of PC utilization (MPCU) [137,139]; and motivational model (MM) [137]. *Consumer theory* is defined as the relationship between consumer preference of goods and services and expenditure; grounded in sociology, the *IDT* model “emphasizes the process by which an innovation or new knowledge is accepted or rejected by a particular group or organization over time” [91]; *TRA* model is based on the

social psychology of human behavior and is used to predict behaviors according to an individual's attitude toward the behavior (positive or negative feelings) and subjective norm (whether a behavior should or should not be performed according to the individual's perception of what people closest to them think); *TPB* is an extension of the *TRA* model with the inclusion of perceived behavioral control which "refers to people's perception of the ease or difficulty of performing the behavior of interest" [97]; *SCT* looks at the relationship between individual behavior, the environment, and people that influence an individual's acquisition and maintenance of behavioral patterns; *SDT* refers to the intrinsic (e.g., inherent satisfaction, personal interest) and extrinsic factors (e.g., compliance, rewards/punishment) for motivation; *TAM* is the perceived usefulness and ease of use that influence an individual's acceptance and use of technology; *UTAUT* refers to how well new technology will be embraced by users based on the factors of performance expectancy, effort expectancy, social influence and facilitating conditions moderated by gender, age, experience and voluntariness of use [138]; *UTAUT2* is an extension of *UTAUT* including hedonic motivation (*i.e.*, perceived enjoyment), price value, and experience and habit without voluntariness as a moderating variable [138]; *MPCU* is derived from *TRA* and *TPB* with a competitive construct to predict user behavior of PCs; and *MM* refers to intrinsic and extrinsic motivational factors to understanding user adoption of new technology. Each model employs a variety of core measurements to ascertain consumer acceptance.

We present the results of our evaluation of social robotics, brain machine interfaces and neuro/cognitive enhancement literature through the lens of core measures of the various technology acceptance models.

2. Experimental Section

Table 1 describes the search strategies for the BMI, social robotics, and enhancement literature. The search took place in May 2012 and RIS files of all the articles found were imported into Knowledge Share (KSv2) [140]. This tool was used to systematically review the literature (abstracts of articles) by process of inclusion/exclusion based on the following criteria: For BMI—*include*: full PDF available, English language, *exclude*: books, conference announcements, purely technical articles; social robotics—*include*: full PDF available, English language, *exclude*: books, conference announcements, purely technical articles; neuroenhancement and cognitive enhancement—*include*: full-text available, English language, within humans and non-rehabilitative (focus on increasing capabilities beyond the "normal", *exclude*: books, conference announcements, purely technical articles. Articles were reviewed for inclusion separately by two researchers; Kappa scores were calculated and any disagreements were addressed individually until a consensus could be reached for the article in question.

Articles which were agreed upon by two researchers were imported into Atlas.ti 7.0.75 a qualitative analysis software and underwent thematic analysis, wherein the texts were coded for content related to the core measures of the different technology acceptance models. Generally, the core measures of each model were evident implicitly in the articles; very few articles discussed or mentioned the actual models or core measures explicitly. The literature was analyzed by two researchers to increase the reliability of our findings.

Table 1. Literature search summary.

Topic	Databases	Keywords	# Articles Found	# Articles Included	Kappa
BMI	ScienceDirect, Scopus, OVID (All), EBSCO (All), Web of Science, and JSTOR	“brain machine interface”	1,058	71	0.99
Social robotics	Science Direct, Compendex, IEEE, Communication Abstracts, Scopus, OVID(All), EBSCO(All), Academic One File, Web of Science, and JSTOR	“social robot”	489	171	0.88
Neuroenhancement and cognitive enhancement	JSTOR, ScienceDirect, PubMed, EBSCO, Academic Search Complete, Web of Science and Scopus (Elsevier)	“neuro- enhancement”, “cognitive enhancement”	361 for neuro- enhancement 1,022 for cognitive enhancement	61 for neuro- enhancement 82 for cognitive enhancement	0.90 for neuro- enhancement 0.79 for cognitive enhancement

3. Limitation

For BMI technology and social robotics, our search terms were limited to “brain machine interface” and “social robotics” respectively, which excluded articles that use different terms such as “brain-computer interface” or “companion robot” to just name two terms. We do not claim that our results cover all the literature for a given product as we used only one term in our search but not all possible search terms (e.g., the term, “brain machine interface” is also referred to as: “neuro prosthesis” or “brain computer interface”) and we did not search every academic database available. However we did perform Google Scholar searches for the keyword combination of for example “brain computer interface” and “technology acceptance model” to see whether it would generate hits that are different to for example using “brain machine interfaces” and “technology acceptance model”. Ten more hits were generated with using BCI instead of BMI. Then we know about the work of for example the group of Nijboer *et al.* which does work pertinent to our research question [141–143]. The output of this group did not appear in the 1,058 BMI articles although Nijboer *et al.* were cited a few times by others. Nijboer *et al.* work relevant to our research question however also did not show up if we changed our search strategy by replaced BMI with BCI in our database searches. Nijboer stated among others that it is important to investigate user experience but that it is rarely done so in current BMI research and that investigating user centered approaches would increase user acceptance [141–143]. In short if one does not cover every article and every database with the least limiting keyword it is to be expected that one might miss some work especially in fields where the terminology is still evolving as is the case in the social robotics and BMI field. However while our search terms limited the articles captured we believe the sample we have is large enough to allow us to reach some conclusions allowing future research that could compare our results with results one might obtain with other keyword combinations. Furthermore we submit that the landscape of results will change down the road as the fields we investigated are still evolving whereby our results reflect the time till May 2012.

4. Results

First we evaluated whether the following technology acceptance models (TRA; TAM; MM; TPB; MPCU; IDT; SCT; UTAUT; UTAUT2; consumer choice; SDT) have been employed already to investigate consumer sentiment toward the three science and technology products (social robots, brain machine interfaces and neuro/cognitive enhancers) covered in this paper. Two of the articles covering social robots looked at the UTAUT model [144,145]; the articles that mentioned the UTAUT model mentioned also TAM and some articles mention TAM as well as TRA, and TPB [146,147]. No article covering brain machine interfaces and neuro/cognitive enhancers mentioned any of the technology acceptance models by name. This finding indicates a possible area of analysis and research around social robots, brain machine interfaces and neuro/cognitive enhancers.

Secondly we looked at whether discourses around social robots, brain machine interfaces and neuro/cognitive enhancers covered aspects that are seen as core measures within the various technology acceptance models even if the models themselves are not mentioned by name. Table 2 reveals the frequency of coverage of various core measures within the articles covering social robots, brain machine interfaces and neuro/cognitive enhancers. In general the neuro and cognitive enhancement discourses covered more of the core measures than social robotics or brain machine interfaces. However if a core measure was covered it was often only covered by one article so there is space for improvement for a more solid foundation of discussion of the core measures even in the neuro/cognitive enhancement discourse. Table S1, found in the supplementary file, give concrete examples from the articles and the 78 references of the articles that covered core measures.

Table 2. Core Measures of technology assessment models covered in the Neuroenhancement, Cognitive Enhancement, Brain Machine Interface and Social Robotics discourse (n = number of articles).

Theory	Core Measure of a Given Theory	Neuro-Enhancement	BMI for Enhancement Purposes	BMI for Restorative Purposes	Social Robotics
Theory of Reasoned Action (TRA)	Attitude Toward It (an individual's positive or negative feeling about performing the target behavior)	$n = 1$	$n = 1$	$n = 11$	$n = 9$
	Subjective Norm the person's perception that most people who are important to him think he should or should not perform the behavior in question	$n = 1$	$n = 1$	$n = 4$	$n = 2$
	Perceived usefulness (increase job performance)	$n = 2$	$n = 1$	$n = 2$	$n = 7$
Technology acceptance model (TAM)	Perceived ease of use	$n = 2$	$n = 1$	$n = 2$	$n = 1$
	Subjective norm	$n = 4$	$n = 1$	$n = 1$	

Table 2. Cont.

Theory	Core Measure of a Given Theory	Neuro-Enhancement	BMI for Enhancement Purposes	BMI for Restorative Purposes	Social Robotics
Motivational model	Extrinsic motivation (users want to perform an action because it's perceived to achieve a valued outcome that is outside of the activity like jobs...)	$n = 5$	$n = 1$	$n = 3$	$n = 1$
	Intrinsic motivation (for no external reason but purely for the process of performing the activity <i>per se</i>)	$n = 10$		$n = 1$	
Theory of Planned behavior	Attitude towards behavior	$n = 1$			$n = 8$
	Subjective norm	$n = 4$	$n = 1$	$n = 1$	
	Perceived behavioral control (the perceived ease or difficulty of performing the behavior) (perception of internal and external constraints on behaviour)	$n = 1$			$n = 2$
Model of Personal Computer (PC) utilization	Job fit	$n = 8$			$n = 2$
	Complexities			$n = 3$	
	Long term consequences (pay-off in the future)	$n = 19$			$n = 13$
	Affect towards use (positive or negative feeling towards it)	$n = 1$			$n = 7$
	Social factors (internalization of the reference group subjective culture, and interpersonal arguments)	$n = 3$			$n = 2$
	Facilitating conditions Objective factors in the environment that observers agree make an act easy to accomplish	$n = 5$		$n = 1$	$n = 13$
Innovation Diffusion Theory	Relative advantage	$n = 18$		$n = 1$	$n = 3$
	Image (enhance one's image)	$n = 9$	$n = 1$		$n = 1$
	Visibility (one can see others using it)	$n = 4$			
	Compatibility (Perceived as being consistent with the existing values needs and past experiences of potential adopters)	$n = 14$			
	Results demonstrability	$n = 5$			
	Voluntariness of use	$n = 4$			
Social cognitive theory	Outcome expectations—Performance (consequences)	$n = 10$		$n = 1$	$n = 2$
	Outcome expectation personal Personal consequence such as esteem and sense of accomplishment	$n = 10$		$n = 1$	$n = 1$
	Self-efficacy	$n = 2$			$n = 3$
	Affect (liking)	$n = 1$			
	Anxiety	$n = 1$			

Table 2. Cont.

Theory	Core Measure of a Given Theory	Neuro-Enhancement	BMI for Enhancement Purposes	BMI for Restorative Purposes	Social Robotics
UTAUT	Performance Expectancy	$n = 10$			
	Effort Expectancy	$n = 1$			
	Social Influence	$n = 4$			
	Facilitating Conditions Age Gender, Experience, Voluntariness	$n = 1$			$n = 6$
UTAUT2	Performance Expectancy	$n = 12$			
	Effort Expectancy	$n = 4$			
	Social Influence	$n = 1$			
	Facilitating Conditions Age Gender Experience	$n = 1$			
	Hedonistic Motivation	$n = 13$		$n = 1$	$n = 2$
	Price Value	$n = 3$			
	Habit	$n = 3$			
	Behavioural Intention			$n = 6$	
Consumer choice	Social factors				
	Family				
	Friends				
	Other people	$n = 1$		$n = 4$	
	Trends				
	Gender				
	Age				
	Entertainment				
	Environmental factors				
	Lifestyle	$n = 5$		$n = 2$	
	Personal factors				
	Needs				
	Wants				
	Likes				
	Time	$n = 3$	$n = 1$	$n = 2$	$n = 3$
	Values				
	Emotion				
	Knowledge				
	Hobbies				
	Economic factors				
	Affordability	$n = 2$		$n = 1$	
	Value for money				
	Psychological factors				
	Planned buying				
	Impulse buying				
	To bribe award or encourage someone	$n = 6$		$n = 2$	
	Emotions				
	Celebration				
	Advertisement				

Table 2. Cont.

Theory	Core Measure of a Given Theory	Neuro-Enhancement	BMI for Enhancement Purposes	BMI for Restorative Purposes	Social Robotics
Social determination theory	Intrinsic motivation				
	Competence				
	Autonomy				
	Relatedness	<i>n</i> = 9		<i>n</i> = 1	<i>n</i> = 6
	Interest				
	Enjoyment				
	Inherent satisfaction				
	External motivation				
	Compliance	<i>n</i> = 11	<i>n</i> = 1	<i>n</i> = 1	
	External rewards and punishment				

Tables 2 and S1 in the supplementary file reveal that the following core measures were not mentioned at all.

The following core measures have not been covered within social robotics: intrinsic motivation (for no external reason but purely for the process of performing the activity *per se*); subjective norm; complexities; visibility (one can see others using it); compatibility (perceived as being consistent with the existing values needs and past experiences of potential adopters); results demonstrability; voluntariness of use; affect (liking); anxiety; performance expectancy; effort expectancy; social influence; facilitating conditions (age gender, experience, voluntariness); hedonistic motivation; habit; behavioural intention; social factors (family, friends, other people, trends, gender, age, entertainment); environmental factors (lifestyle); personal factors (needs, wants, likes, time, values, emotion, knowledge, hobbies); psychological factors (planned buying, impulse buying, to bribe award or encourage someone, emotions, celebration, advertisement) and intrinsic motivation (competence, autonomy, relatedness, interest, enjoyment, inherent satisfaction).

As to neuro and cognitive enhancement we did not find articles covering voluntariness and behavioural intention. Only one study really looked at social factors. Competitiveness is the one environmental factor covered.

As for BMI articles, the following core measures have not been covered: long term consequences (pay-off in the future); affect towards use (positive or negative feeling towards it); social factors (family, friends, other people, trends, gender, age, entertainment) (internalization of the reference group subjective culture, and interpersonal arguments); voluntariness of use; self-efficacy; affect (liking); anxiety; performance expectancy; effort expectancy; social influence; facilitating conditions (age, gender experience) and hedonistic motivation. Some core measures are mentioned within the restorative discourse of brain machine interfaces but not within the enhancement discourse of brain machine interfaces. For example: environmental factors (lifestyle); personal factors (needs, wants, likes, time, values, emotion, knowledge, hobbies); psychological factors (planned buying, impulse buying, to bribe award or encourage someone, emotions, celebration, advertisement); intrinsic motivation (competence, autonomy, relatedness, interest, enjoyment, inherent satisfaction) and external motivation (compliance and external rewards and punishment).

As for the core measures mentioned (Table S1 in supplemental file) the sentiment revealed in all our case studies was positive and negative. In the case of neuro/cognitive enhancement the core measures of attitude and subjective norm were negatively covered with perceiving negative consequences. Economic gain, competitiveness and efficiency were mentioned as external motivators and performance at school and work were mentioned as internal motivators. These were mentioned factual without judgment. As to long term consequences some mentioned were positive such as economic gain and some were negative such as increased inequity, undetermined safety and increase norms making the non-compliant feeling deficient. As to factors that make it easier to take up enhancement positive media portrayal was mentioned. As to the core measure of compatibility it was seen that our desire for being competitive, being efficient and being able to achieve economic gain was fitting well with neuroenhancers whereas neuroenhancers were seen as incompatible with values of safety, free will and equality. Male were seen of being more in favor of enhancements. As to psychological factors coercion was mentioned as was commercialization and media portrayal.

In the case of BMI applications, authenticity was revealed under the core measure of attitude toward the use of BMI as an enhancement. The attitude toward authenticity is viewed as the genuineness of one's skills, talents and abilities if it is enhanced by BMI technology, and the authenticity of 'free choices' with the pressures of consumerism of technology was thematized [25]. Authenticity was revealed as an extrinsic motivation in the MM model defined as one's ability to "lead a more authentic life" through the use of BMI as an enhancement. This shows a sentiment toward how one is perceived using BMI as an enhancement versus what one envisions as possibilities with its use. Through the TRA model, the subjective norm of BMI for the purpose of enhancement is around the sentiment of the novelty of BMI technology and weighing costs and benefits but from the perspective of using BMI for restorative purposes, the subjective sentiment is more favorable toward potential improvement of one's quality of life.

In the case of social robotics there was particular focus on core measure related to attitudes toward social robots ($n = 9$ in TRA, $n = 8$ in TPB, $n = 7$ in PC utilization), perceived usefulness ($n = 7$), long-term consequences ($n = 13$ in PC utilization), and facilitating conditions such as age ($n = 13$ in PC utilization, $n = 6$ in UTAUT). In general, articles explored positive personal experiences with robots such as entertainment value, pleasure gains, and increased independence, with some noting that older generations are generally less accepting of technology [148], and overly human-like robots would be perceived as creepy [149,150]. Perceived usefulness included social robots taking over dangerous jobs, and relieving human resource pressures (especially in eldercare).

5. Discussion

5.1. Uses of Technology Acceptance Models

The Technology Acceptance Model (TAM) was initially developed to explain what makes end-users accept a wide range of computing technologies [135]. TAM focuses on perceived ease of use and perceived usefulness. In the original 1989 paper, Davis defined perceived ease of use as "the degree to which a person believes that using a particular system would be free from effort" and perceived usefulness as "the degree to which a person believes that using a particular system would

enhance his or her job performance” [135] and proposed that perceived ease of use affects perceived usefulness. One study using TAM to look at human-computer interactions in high school students in Taiwan found that perceived ease of use can predict perceived usefulness and perceived usefulness can predict perceived ease of use; moreover, perceived ease of use and perceived usefulness can predict attitude toward using [151].

Five studies in the BMI literature we covered mentioned ease of use as important for BMI success [28,37,152–154] whereby these studies focused on the non-invasive version of BMI's. Indeed others looked at the linkage of invasiveness and acceptability outside BMI [155]. As to perceived usefulness, it is recognized within the BMI literature that “perceived usability can be described by many factors including ease of use, controllability (*i.e.*, speed, accuracy, responsiveness, sensitivity), effectiveness of technology, effectiveness of mental approaches, cosmesis, and overall satisfaction” [152]. Various articles covered perceived usefulness whereby this was mostly discussed within the framework of whether an invasive or non-invasive BMI version is more useful. One study investigating the perception of special education teachers on BMI [41] found that ease of use was a major concern that special education teachers voiced in regards to their disabled students using a BMI. The same study revealed that special education teachers envisioned that BMI's have the potential of being useful by furthering the independence, social participation and quality of life of the special education student [41] but they also believed that invasiveness decreases the usefulness of BMI's. However special education teachers also voiced other parameters which one would not list under the two parameters of TAM such as affordability, need for being invisible as they feared that their students would get ostracized if their new device were too visible, reliability of the device and concern related to reaction of peers [41].

The issue of “ease of use” is also covered in the social robotics literature. Seven social robotics articles mentioned ease of use as important [13,144,146,148,150,156,157]. As to perceived usefulness, $n = 16$ articles covered this angle with two articles reporting on survey results [158,159]. However within the social robots literature it is also realized that one has to go beyond ease of use and perceived usefulness. One article states that there is a need for “design guidelines as to how to develop socially acceptable robots to be used for social skill intervention for children with ASD (autism spectrum disorder)” [160]. Given the realization that TAM is too limited some of the social robotics literature engaged with technology acceptance models which was not evident in the BMI literature. Some articles looked at the UTAUT model [144–147] which went beyond ease of use and perceived usefulness including various other factors. The Almere model was developed by modifying the UTAUT model further to adapt it to social robotics special needs by adding measures such as perceived sociability, social presence, social influence and perceived enjoyment [144]. Another study added user needs as a parameter [161]. Others went on to modify the Almere model further whereby the authors followed the concept of product ecology [162].

As to neuro/cognitive enhancements, none of the technology acceptance models were mentioned. We also obtained no hits if we use “consumer acceptance models” which is another area of inquiry that tries to understand consumer behavior and might be useful. Interestingly, Donovan, Egger, Kapernick and Mendoza investigated in 2002 what might prevent so called non-disabled athletes from taking illegal performance-enhancing drugs in Sport. They found that the likelihood of drug use will be highest when (a) threat appraisal is low (b) benefit appraisal is high (c) personal morality is neutral (d) perceived

legitimacy of the laws and enforcement agency is low (e) relevant reference groups are supportive of drug use and (f) high vulnerability on personality factors (e.g., low self-esteem, risk taker, pessimist) [163].

We submit that acceptance models have a useful role to play in informing not only researchers and engineers but also policy makers as to how a product should be developed, what might drive demand for the product and what the impact might be of the drivers of the product that become evident in the acceptability investigation. Within the frame of health care, this data is for example important, as many of these non-restorative enhancements might be delivered through the health care system [25,58] making them part of the discourse around health consumerism and consumer personalized medicine [164–167].

5.2. Modified Technology Acceptance Models

The original TAM has been modified by many. Some changes were linked to the field of application such as adding compatibility as a factor to investigate the uptake of information systems by health professionals in Canada [133]. Some changes were linked to the place investigated; one study investigating factors impacting innovation in a product development organization found that organizational support, cost-effectiveness, system quality, organizational need, and functional effectiveness were predictors of uptake [168]. Some changes were linked to social groups such as one study that added internal and external motivation [169] when they investigated older people; the UTAUT2 model added gender as a parameter. Musa modified TAM to be more applicable to development purposes and added “the linkages between factors of national development (socioeconomic development) and technological infrastructure (as captured by accessibility to technology)” and captured also “individuals’ perceptions of the negative and positive impact factors” [170].

We submit that no one model in our table encompasses all the facets needed to investigate acceptance and consequences of various non-restorative enhancements; however, modified versions of models such as the UTAUT and consumer choice model and combinations of the ones we looked at could still be useful.

It is believed by some that the existing technology acceptance models are not able to drive design, but are used only to verify designs [171]. The applications we cover in this paper are still emerging and are still open to changes in trajectory as to how they will be implemented, how they are employed, and with what consequences. For the results to be able to drive design, we submit that open-ended questions should be used in acceptability investigation questionnaires to obtain a differentiated picture of what people think about the products, especially around social context, social factors, and internal and external motivations. For example in the case of marginalized populations such as disabled people, we need a way to ascertain their views not only within the framework of being a patient population but also within a framework of self-understanding where the disabled person does not perceive themselves as impaired [58]. We also have to understand who wants or does not want neuro or other forms of enhancements and why people want or do not want neuroenhancements, BMI or social robots. This knowledge is important for the product generators.

Some social robotic groups modified the UTAUT to include core measures that would fit their product, and BMI is seen to be in need of a more tailored evaluation [141–143]. We submit that human-centered designs [172–174] (or user centered design [142]) and a participatory design

process [175,176], which involves co-designing with generative design tools [177], is one possible avenue that could be utilized more by researchers and engineers. The participatory design could start with a modified UTAUT with open-ended questions covering design, needs, motivation and social factor consideration. This is an especially good starting point for emerging products which are not readily available to the public (as in the case of the products highlighted in this article) to defuse the critique that the acceptability models are used only to verify design rather than drive it [171].

Open-ended questions covering design, needs, motivation and social factor consideration ascertain information on the designs wanted and needed, but also generate information on what makes the product desirable, where funding should be sourced from (for development and for the actual purchase down the road by the consumer), and the social factors and contexts influencing the product acceptance. This information will be useful for the design and the ethical, legal, economic, social and policy discourse around the product's development and as such should be gathered as early as possible. While it is not feasible to consult with every potential user on the design of a product, developing and applying a well-rounded acceptability model can generate a better understanding of the social context around the acceptance or rejection of a product, in addition to helping verify or disprove a design.

6. Conclusions

We submit that, in general, all three discourses under-investigate the different facets of what makes people accept or reject a given product. There is space for improvement for social robotics, brain machine interfaces and neuro/cognitive enhancement discourses as to investigating the sentiments of people towards the emerging products.

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Conflict of Interest

The authors declare no conflict of interest.

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