George Edward Torrens, Loughborough Design School, Loughborough University, UK

she ji
[ʃə: dʒi:]

Dialogue Appropriate to Assistive Technology Product Design: A Taxonomy of Communication Formats in Relation to Modes of Sensory Perception

Abstract This article reviews the use of dialogue and associated communication formats within the context of participatory or co-design decision-making processes in the development of assistive technologies. My professional experience as a designer, researcher, and educator suggested the dialogue among the designer, end-user, and associated stakeholders is critical to effective and economic product development. The research I report on here is a systematic analysis of that understanding. First, I conducted a literature review which established that there was no standard meaning for the term "dialogue." The literature review highlighted the challenges of reduced options for communication through the compounding constraints of culture, language, and impairment. I then conducted a summative content analysis on twenty case studies to identify and define the terminology and points to consider in collaborative dialogue between designers and people who need assistive technologies. This analysis led to the development of a taxonomy of communication formats matched to specific sensory inputs and these have been structured to work as a heuristic design tool. Of the forty-one formats defined, around two-thirds were used in the literature reviewed. Notably, more than half the studies used just over a quarter of the formats. The definitions of dialogue and the design heuristics I put forward in this paper require further debate and refinement to be effective to wider applications.

Introduction

I have been an industrial designer for nearly thirty years and most of that time has been spent in the field of assistive technology product design. This is a product area that makes a substantial contribution to the economy. In the United Kingdom, the Institute of Export and International Trade states that, "The social care market, dominated by assistive technologies and private care homes, is set to grow from £2bn in 2012 to £6bn in 2020 due to the demand for delivery of care closer to home."[1] Globally, more than one billion people need at least one assistive product.[2]

The World Health Organization defines this field to include assistive products, services, and systems related to the delivery of these products and services. This paper is situated in the area of assistive technology products. These are products that maintain or improve the function and independence of individuals who use them to enhance their well-being. Examples of assistive technology products include hearing aids, wheelchairs, communication aids, spectacles, prostheses, pill organizers, and memory aids.

As a practicing designer, researcher, and design educator, I have used and taught participatory design methods. One important element of this method is that dialogue among the designer, end-user, and associated stakeholders is critical to effective and economic product development.[3] Participatory design, as a method of generating physical products or services, is used in disciplines from sports coaching to business and social policy.[4] I argue that this method would be enhanced if designers used communication formats that match the sensory input of the individuals with whom they are working.

In this article, formats of communication refer to: spoken word, music, or audible sounds; acting out an activity (role play) and movement; two dimensional visualizations such as line drawings and photo-realistic images; and, three-dimensional models, from simple esquisse or sketch models made from cardboard or foam to fully working prototypes. Industrial designers often use a combination of these communication formats during a design process – a choice based on personal experience rather than research.

What is missing, in existing literature, is research regarding the appropriate communication formats for various contexts. This article clarifies the contexts in which different types of communication formats are used in the design process. It presents a taxonomy of communication formats matched to particular sensory inputs; structured to work as a heuristic design tool. The research question addressed in this article is: What are the appropriate communication formats to apply to dialogue as part of a user-centered, participatory approach to assistive technology product development?

Definition of Terms

Reviewing conventional formats for industrial design requires a definition of the practicing designer. I formulate the concept in this way: an industrial designer contributes to social and cultural function or value by embedding cultural coding in a product or service and manipulating viewers' or users' perceptions of it within the constraints of cost and time. Practicing industrial designers are often paid for their time on an hourly rate or predict the time it will take to do a specific job and quote a 'flat rate' for the work. In either case, there is a finite time a client would wish to pay for research or exploration of options before receiving a definitive outcome. Assistive technology product design is part of industrial design. Assistive technology design focuses on the providing products (predominantly) used to increase, maintain, or improve the functional capabilities of individuals with one or more disabilities.[5]

1 The Institute of Export & International Trade, "Unlock Your Global Business Potential: UK Medical Technology," Accessed December 11, 2017, https://opentoexport.com/article/unlock-your-global-business-potential-uk-medical-technology/.

2 "Assistive Technology," World Health Organization, accessed December 10, 2017, http://www.who.int/mediacentere/factsheets/assistive-technology/en/.

3 Nigel Cross, *Design Participation* (London: Academy, 1972), 11–14; Geof Mercer, "Emancipatory Disability Research," in *Disability Studies Today*, ed. Colin Barnes, M. Oliver, and L. Barton, (Oxford: Blackwell, 2002), 228; Donald A. Schön, *The Reflective Practitioner: How Professionals Think in Action* (Farnham: Ashgate, 1991), 76; Donald A. Schön, *The Design Studio: An Exploration of its Traditions and Potential* (London: RIBA, 1985), 1–8.

4 Sid Hayes and Gary Stidder, *Equity and Inclusion in Physical Education and Sport* (Abingdon: Routledge, 2003), 1; Bjirn Gustavsen and Per H. Engelstad, "The Design of Conferences and the Evolving Role of Democratic Dialogue in Changing Working Life," *Human Relations* 39, no. 2 (1986): 101; John S. Dryzek and Carolyn M. Hendriks, "Fostering Deliberation in the Forum and Beyond," in *The Argumentative Turn Revisited: Public Policy as Communicative Practice*, ed. Frank Fischer and Herbert Gottweis (London: Duke University, 2012), 31.

5 World Health Organization, "WHO Global Disability Action Plan 2014–2021: Better Health for All People with Disability," accessed December 11, 2017, http://apps.who.int/iris/bitstream/10665/199544/1/9789241509619_eng.pdf.

6 Janni Nielsen, Lone Dirck-inck-Holmfeld, and Oluf Danielsen, "Dialogue Design–With Mutual Learning as Guiding Principle," *International Journal of Human-Computer Interaction* 15, no. 1 (2003): 21, DOI: https://doi.org/10.1207/S15327590IJHC1501_03.

7 Jennifer C. Greene, "Dialogue in Evaluation: A Relational Perspective," *Evaluation* 7, no. 2 (2001): 181, https://doi.org/10.1177/135638900100700203.

8 Paul Gorsky and Avner Caspi, "Dialogue: A Theoretical Framework for Distance Education Instructional Systems," *British Journal of Educational Technology* 36, no. 2 (2005): 137, DOI: https://doi.org/10.1111/j.1467-8535.2005.00448.x.

9 Rachael Luck, "Dialogue in Participatory Design," *Design Studies* 24, no. 6 (2003): 523, https://doi.org/10.1016/S0142-694X(03)00040-1.

10 "Ex Libris Software," Ex Libris, last modified December 11, 2017, http://www.exlibrisgroup.com/.

11 "Google Scholar," Google, accessed December 11, 2017, https://scholar.google.co.uk/.

The term dialogue also requires definition. A dialogue is a conversation between two or more individuals.[6] The term began in Asia and the Middle East as a form of philosophical discussion or argument. While the idea predates the time of Socrates and Plato, Plato's rendition of Socratic dialogue has become a central concept in the use of the term. In more modern times, people in education and business use the concepts of egalitarian dialogue[7] and dialogic learning[8] Interlocutors evaluate contributions based on validity reasoning among equal levels in structured dialogue.[9] This form of dialogue often leads to problem solving.

Problem solving through dialogue may take the form of counselling or it may constitute part of a design process. In the context of new product development for assistive technology, designers use dialogue to create meaning and to understand an end-user's needs and aspirations. Understanding an individual or group of individuals in dialogue requires effective communication. Transmitting meaning among individuals or groups requires using both mutually understood signs and semiotic rules.

The purpose of effective communication in this context is to elicit social influence. Social influence is associated with individual conformity, compliance, and obedience. It occurs when an individual's emotions, opinions, or behaviors are affected by others. The forms of influence may be through socialization, peer pressure, leadership, sales, and marketing. Social doctrines are the principles taught by a political party or religious group that are part of social influence. Sales and marketing are the two forms of social influence that are the background for this article.

Method

I employed an applied science structure for this study. My professional experience suggests that this is a format that is easily used by industrial designers since much of their product development work aligns closely with engineering.

The steps undertaken in this study were:

1. Through the literature review
   a. define context for dialogue between end-users and designers of a product;
   b. identify available design specific communication formats; and
   c. identify unique communication formats;
2. Summative Content Analysis of 20 published Assistive Technology product development case studies to:
   a. identify which of these formats have been applied with associated end-user impairments;
   b. define social, cultural doctrines associated with a range of impairments; and
   c. produce a taxonomy — a heuristic design tool look-up table — of impairment against suitable formats of design specific communication.

Literature Review

The focus of the literature review was to identify existing and well-established communication formats. The terminology used in that search was based on UK design and assistive technology product design definitions and perspective. The literature review identified dialogue and communication formats in industrial design, targeting handheld or body-worn assistive technology necessary in daily life.

To define the scope of the research to be covered, I limited the review to two meta-search engines: catalogue plus,[10] and google scholar.[11] The keywords and phrases used were: dialogue within design, design communication, design formats of communication, industrial design, product design, assistive technology, inclusive design, universal design, user centered design, dialogue, communication, and augmentative

and alternative communication. Aspects of communication, such as information theory (quantification of information, storage and digital transmission) and biosemiotics (communication among organisms other than human beings) were considered outside the scope of the study.

This review revealed that the term dialogue did not have a standard definition; nor was there a consensus for describing communication formats. In some cases, the formats were derivations of or hybrids taken from other disciplines—fine arts, architecture, engineering, and literary studies. The literature review focused on well-established communication formats associated mainly with physical impairment, e.g., visual, auditory, olfactory, physical sensation, movement, or vocal, that included descriptions of the mechanisms for sending and receiving particular types of communications. The communication format needs of those with cognitive impairment, such as individuals on the autistic spectrum or with learning difficulties were considered in this study but require a separate review in order to fully define useful formats for that population.

I targeted the communication formats that designers use in conducting participatory design of user-centered and human-scale design processes of hand-held or body-worn assistive technology products (including wheelchair accessories). This excluded predominantly engineering (function only), and architectural (large-scale) formats relating to physical manufacturing, materials, and systems. Designing of secondary medical devices, such as those used, for example, in hospitals, interior design, and architecture, including accessibility and space design, lay beyond the scope of the review. Similarly, the review excluded the issues of creativity and innovation, due to limited time and resources. I deemed the translation of numeric information into graphic communication formats (information design) to also be outside the scope of my study.

The United Kingdom's support and funding structures for healthcare provided the terminological context for the study, with references to other healthcare structures translated into United Kingdom terms. The terminology of definitions related to this field of Design discipline were from a UK context and perspective, as discussed and defined by Cross,[12] Jones,[13] Potter,[14] Archer,[15] and Tovey.[16] The review did include design decision-making during the design process in each case study, but only with regards to its effective application to communication formats.

The reviewed journals, textbooks, and standards assumed some background knowledge of design or engineering. I placed no time limit on the publication date of textbooks or articles, as many of the defined communication formats are as old as humanity.

My emphasis on well-established definitions of communication formats in industrial and assistive technology product design focused the review. British standards for management of new product development processes relating to industrial design and assistive technology or inclusive design provided the context.[17] This standard works within the context already given about generic design process and the constraints of current UK healthcare provision. I engaged in an iterative cycle of review, including data mining of authors of interest, as well as associated reference lists from articles and textbooks. The keywords used in the initial survey were used in the main survey, providing a manageable number of references for a single reviewer.

I used my experience and professional expertise in the field of industrial and product design to make qualitative decisions about duplicate communication formats from different sources. Communication formats were initially identified by name, with each article or chapter checked to ensure it matched the protocol conventions associated with it. Where not clearly defined, protocol descriptions were used to identify communication formats by matching them to similar descriptions

12 Cross, *Design Participation.*

13 John C. Jones, *Essays in Design* (Chichester: John Wiley & Sons, 1984), 15–27.

14 Norman Potter, *What is a Designer: Education and Practice, a Guide for Students and Teachers* (London: Studio Vista, 1969), 9–24.

15 Bruce Archer, "Design as a Discipline," *Design Studies* 1, no. 1 (1979): 17, DOI: https://doi.org/10.1016/0142-694X(79)90023-1.

16 Michael Tovey, "Styling and Design: Intuition and Analysis in Industrial Design," *Design Studies* 18, no. 1 (1997): 5, DOI: https://doi.org/10.1016/S0142-694X(96)00006-3.

17 British Standard, *BS7000-6:2005, Design Management Systems: Managing Inclusive Design: Guide* (London: British Standards Institute, 2005); British Standard, *BS EN ISO 9999:2011, Assistive Products for Persons with Disabilities—Classification and Terminology* (London: British Standards Institute, 2011).

18 George E. Torrens, "The Order and Priority of Research and Design Method Application within an Assistive Technology New Product Development Process: A Summative Content Analysis of 20 case studies," *Disability and Rehabilitation: Assistive Technology* 13, no. 1 (2018): 66, DOI: https://doi.org/10.1080/17483107.2017.1280547.

19 Virginia Braun and Victoria Clarke, "Using Thematic Analysis in Psychology," *Qualitative Research in Psychology* 3, no. 2 (2006): 77.

20 Hsieh Hsiu-Fang and Sarah E. Shannon, "Three Approaches to Qualitative Content Analysis," *Qualitative Health Research* 15, no. 9 (2005): 1277.

21 Louis Cohen, Lawrence Manion, and Keith Morrison, *Research Methods in Education*, 7th ed. (Abingdon: Routledge, 2013), 34, 85.

in other texts, in the context of their application to the processes of new product design.

The literature review covered all aspects of communication within design to obtain a topography of all textbook/well-established terminology and formats of communication. What this review did not tell us is the frequency that these descriptions are used in applied design processes.

Summative Content Analysis

I conducted a summative content analysis of twenty case studies to provide insights into the frequency that these descriptions are used in applied design processes within the context of the United Kingdom healthcare market. I previously undertook a similar study with the same case studies to analyze the design and research methods applied in them.

The twenty case studies from the field of Assistive technology product design were identified from available sources, including journal articles and textbooks from a previous published literature review into research methods.[18] Ten of the case studies are my own work and ten from published studies found through the literature review. I used my papers to develop a template protocol for the analysis and to identify keywords that matched specified communication formats in each text. I chose the studies from other authors to match the level of focus and detail at which my ten case studies were described, i.e. method only; combined methods; and, methodology or approach.

I drew upon summative content analysis, a derivative of thematic analysis,[19] to identify end-user impairments and the associated communication format employed in each case study.[20] Cohen et al. define case study as a research method involving in-depth and detailed examination of a subject of study (the case), within related contextual conditions or environments.[21] The case studies were analyzed to: A) describe the context of the new product development; and B) identify the communication formats employed in that process. I explored the application of communication formats with individuals living with impairments through a review of specific keywords. Circumscribing the literature review limited expectations, focusing on material within the professional practice of industrial design and the field of assistive technology product design. The review process comprised two parts: 1) identifying aspects of dialogue context that correlate with specific forms of impairment; and 2) a summative content analysis of published case studies to identify the communication formats appropriate for those impairments.

While statistical validation of outcomes was mentioned in the case studies, the communication of formats through tables of numbers was not considered as conventional design-specific communication formats. The translation of numeric information into graphic communication formats (information design) was also considered outside the scope of this study.

Two operators reviewed the twenty case studies, using the same protocol, to minimize bias. Both operators employed the same list of communication formats, which included a short description of each format. The operators used the descriptions to identify the formats in each study. I was one of the operators, with the other an administrator with good working knowledge of design methods. Using an operator not fully immersed in design processes ensured the descriptions were reviewed on the content alone, and prevented me, as an experienced designer, from unintentionally 'filling in' any gaps. We compared our reviews to identify any differences or anomalies between our interpretations of each case study, and then discussed them. When one of us identified a format the other had not perceived, we reviewed the reasoning for identification and decided jointly whether or not to

include or exclude the element. Due to constraints on time and resources, we did not give consideration to the novelty of any excluded identified communication formats or the need for new categories. Externalizing our reasoning also help us to resolve differences in interpretation.

Results and Discussion: Literature Review Findings

I reviewed over 120 articles, textbooks, and standards but I only include those directly referenced in the text. The other operator and myself considered the literature review outcomes in the British context of a social model of healthcare (treating the person), rather than a medical model (treatment of symptoms).[22]

The dialogue that takes place during the design process may be formal, turn-taking and constrained, or reciprocal with both or multiple agents interacting simultaneously. The latter provides for spontaneity and potential creativity, but the former is more easily auditable for later analysis and has less 'noise.' Noise in this context means:

- interference from multiple sources, making perception of meaning more difficult;
- environmental, physical interference between communications sent and the ability of the receiver to perceive them (including impairment);
- mismatched meaning of coding, including different cultural contexts for sender and receiver; and
- the psychological or emotional state of both sender and receiver.[23]

Human beings are not well equipped to process multiple signals such as when two or more people are talking at the same time or if there are people talking in the background. Individuals living with cognitive impairments like autism may experience increased difficulty processing multiple signals. This may also include background mechanical or other noises, often referred to as signal to noise ratio. Physical impairment of sensory organs can have a similar effect to that of external noise. For example, macular degeneration of the eyes (blurred or no sight at the center of the field of vision), often linked with conditions such as diabetes in old age, impairs viewers' perceptions of sketches and electronic presentations. Moreover, tinnitus, a loud ringing in the ears associated with hearing damage from working in loud environments, impairs verbal communication.

Disparate socioeconomic statuses of individuals engaging in dialogue, e.g., office worker and manager, soldier and officer can compound mismatches in cultural coding. Different cultural contexts may also affect a lack of understanding. For instance, white clothing connotes health, youth, and wedding celebrations in British society, but death in Japan. Emotion may drive the response to a visual or audible communication format, as a result of the receiver being calm and open, or agitated and closed. Bias may occur if the sender's communication includes aggressive body language or, contrarily, a gentle tone of voice. The visual and performing arts manipulate these very elements so as to affect audience response.

Examining the communication formats suitable to participatory and co-design activities reveals their benefits as additional design tools merit consideration. Colin Ware[24] provides a good description of the benefits that information visualization can bring to design decision-making that apply to all communication formats. The benefits of using different communication formats in co-designing include the ability to:

- scale using given formats so as to see complex systems, as well as individual detail (for example, using a functional prototype and then examining surface texture or part line);

22 Maggie Conway, *Occupational Therapy and Inclusive Design: Principles for Practice* (Oxford: Blackwell, 2008), 3–34.

23 Klaus Krippendorff, *The Semantic Turn: A New Foundation for Design* (London: CRC Press, 2006), 207.

24 Colin Ware, *Information Visualization: Perception for Design*, 3rd ed. (Amsterdam: Elsevier, 2012), 1.
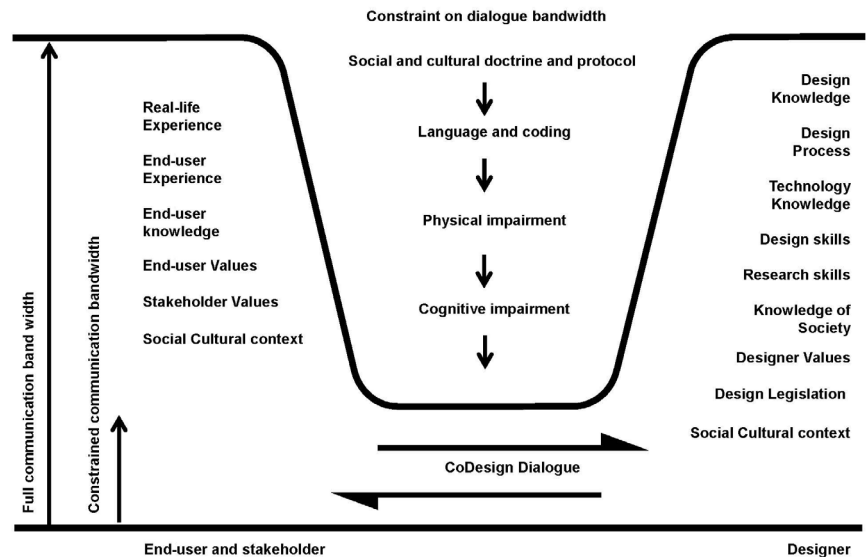
- identify issues, such as features or other characteristics that are inappropriate (such as weight, color, styling, shape, size, or noise made during use);
- provide end-users with opportunities to interact with a thing that they have not previously imagined or considered (I have frequently suggested concepts during a co-design activity to which the end-user has said, "I didn't know you could do that"); and
- enable the designer to gain insights into novel requirements and aspirations of end-users and stakeholders (for example, when the end-user uses a prototype or service in an unexpected way or suggests alternative uses not previously considered).

Different languages, cultures, and doctrines are the conventional constraints in facilitating the exchange of concepts, knowledge, and meaning. However, physical and cognitive impairments may compound these constraints. The diagram in Figure 1 shows how culture, language, and impairment may narrow the conduit for communication. In some cases, the end-user's input may be simply binary (yes/no) or the designer(s) may contribute limited image complexity, color, or contrast that enable the end-user to fully comprehend communications.

When designing an assistive technology product there are multiple challenges related to participatory or co-design during new product development. These include:
- self- and societal perception of people with physical or cognitive impairment;
- language spoken by the individual, their family, community, and society;
- stigmas associated with specific assistive technology products;
- etiquette used in introductions between those participating;
- end-users' past experiences working with designers; and
- questions of trust.

My own experiences working with people who live with physical and cognitive impairments suggests that they sometimes have difficulty maintaining their self-confidence and social status. This may be due to pain related to the tasks involved in daily activities or not being able to complete those tasks. Knowing you may drop a cup of hot tea between the kitchen and living room due to a tremor or lack of balance or hesitating to engage in gardening because you are aware that you

will feel arthritic pain an hour later contributes to being less than confident about performing the activities that comprise daily living. To enable such individuals to externalize their needs and aspirations requires me as a designer to remain quiet and still, and to maintain non-threatening body language, so that I may listen and observe. This discipline has been a difficult to learn, as we designers are trained to be proactive and offer suggestions.

Reviewing literature on end-users' medical conditions, socioeconomic statuses, group blogs, as well as engaging in empathic modelling before an initial meeting enables a level of empathy to be acquired for the needs of end-users. Such preparations lead to the trust that enables a free flow of concepts. Part of my task as a designer is to be mindful that positive framing of all aspects of co-design dialogues is essential to ensuring useful outcomes and minimizing any reservations the end-user or stakeholders may have during the course of the activity. This approach aspect aligns with Maslow's hierarchy of need in creating motivation,[25] the four pleasures or domains cited by Jordan,[26] and Norman's affordances in the context of material culture.[27]

In 1943, Abraham Maslow proposed his initial categorization and hierarchy of five needs (listed, rather than displayed in a pyramid as shown in later interpretations):

1. Self-actualization
2. Esteem
3. Love
4. Safety
5. Physiological (Homeostasis)

He labeled the bottom four "deficiency needs" or "D-needs" with self-actualization, being 'at peace with one's self,' at the top. The D-needs pertain to an individual's survival, procreation, love, and status within society. Maslow also provided thirteen points, which were summarized conclusions from his studies and observations. Key points from his summary relevant to this review are: 5) an act or behavior has more than one motivation; 9) classifications of motivations must be based on goals rather than external drivers; and 13) while behavior is almost always motivated, it is also biologically, culturally, and situationally determined. These observations by Maslow align with points for consideration when initiating dialogue with people living with impairment and disability.

Patrick Jordan's four domains are based on work by anthropologist Lionel Tiger. Jordan defined the four domains or pleasures to provide a structure for the social influence of product branding and product design. The four pleasures are defined as:

- physio-pleasure is an individual visceral experience and interaction with an object (through taste, touch, or smell);
- socio-pleasure is about relationships with others (such as facilitation, communication, shared experience, or identity, status, and belonging through etiquette of greeting, colloquial, or local dialect language, wearing a badge or uniform);
- psycho-pleasure is the mental and emotional reaction or response to physical stimuli and functional usability evoked when undertaking a task, performance, or interaction with a product or service (which is individual, motivational, evocative of past experiences, and may include a sense of place); and
- ideo-pleasure, which has to do with people's values and aspirations (such as environmental issues, animal welfare, and social equality).

Norman's affordances align with Jordan's categorization of pleasures. Norman's visceral response correlates to physio-pleasure, behavioral responses to socio- and

25 Abraham H. Maslow, "A Theory of Human Motivation," *Psychological Review* 50, no. 4 (1943): 370.

26 Patrick W. Jordan, *Designing Pleasurable Products: An Introduction to the New Human Factors* (London: Taylor and Francis, 2002), 11–57.

27 Donald A. Norman, *The Design of Everyday Things* (New York: Basic Books, 2002), 9–12; Donald A. Norman, "Affordance, Conventions, and Design," *interactions* 6, no. 3 (1999): 38.

28 James J. Gibson, *The Ecological Approach to Visual Perception* (Boston: Houghton Mifflin, 1979), 15–17.

29 Helga Dittmar, *The Social Psychology of Material Possessions: To Have is to Be* (New York: St. Martin's Press, 1992), 1–16.

psycho-pleasure, and reflective to ideo-pleasure. Norman's developed his affordances, which focus on practical design applications and human-machine interactions, from terms psychologist James Gibson first proposed.[28] Norman suggests various ways in which an individual (actor) is likely to interact with an object (action). Gibson's original proposal allowed for any possible action by an actor. For example, a door handle may offer only one convenient way for an individual to grip it: pull, turn, or push as the action to open the door. This has direct relevance to the choice of communication format that best presents the affordances of the assistive technology product or service and enables adequate levels of interaction in order to receive feedback regarding the effectiveness of the ideas, concepts, and prototypes presented. Breaking down the complexity of interactions using the theories of affordances and the four pleasures gives designers the opportunity to address specific aspects of end-users' requirements and to test those against responses given during a co-design dialogue. A designer can then build the complexity of the interaction, knowing that she or he has already tested the individual components separately. The hierarchy and highlighted points comprise part of a checklist with which to choose an appropriate communication format.

Material culture, as Helga Dittmar defines it,[29] is the value that individuals and society give to objects, their use, consumption, and associated behaviors or doctrines. This is particularly relevant in westernized societies, based on a system of private property and focused on materialism. In the context of material culture and social doctrine, we can now consider the individual aspirations of people living with impairments or disabilities. The socioeconomic aspirations of such people are unlikely to be different from those of anyone else in a given society. However, the specific functional needs and requirements of their everyday, assistive products are likely to classify them as part of a 'niche' market. From the author's experience, niche markets by their nature possess specific terminology, nomenclature, and associated belief systems. This applies to niche markets for recreational activities such as scuba diving in the same way that it applies to niche markets for professional groups, such as police officers.

The proper etiquette to employ with specific niche market social groups requires research in order to ensure that introductions are made correctly. Considering etiquette is also a requirement in most research protocols that follow ethics conventions. The benefits of applying appropriate etiquette include: demonstrating respect for the participant as an individual; providing an indication that the designer-researcher has taken time to consider the participant's values and beliefs; and, making clear their value in the participatory research or participatory design process. All lead to the participants being more likely to trust the designer-researcher, enabling an open and frank dialogue. The consequences of ignoring proper etiquette can include the end-user perceiving the designer-researcher as insulting or disrespectful. This tends to reduce any form of dialogue, if it does not shut dialogue down completely. It can lead to anger, verbal, and — in an extreme situation — even to physical conflict.

As an example, designers should consider several aspects of etiquette and communication format during a participatory design activity for blind individuals or those with visual impairment. For this group, these issues may include:

- announcing verbally who you are when you come into a room or space, so the person is aware of your presence;
- only making physical contact with an individual when she or he indicates a desire for contact, for example, extending a hand in greeting;
- making explanations in appropriate formats, for example, speaking aloud without pointing or gesturing;
- providing orientation and distance for activities or demonstrations of products and tasks;

- using sound for orientation and describing distances from the individual in terms of limb lengths; and
- using appropriate communication aids, such as simple, high contrast sketches(for those with some vision), material samples, or functional models (weighted to match the center of gravity of the proposed product).

Issues of orientation, task context, and use protocols are innate to developing the handling and usability of any new industrial design product. I contend that all designers should apply the rigor of reviewing end-users' social and cultural references before engaging in participatory or co-design. For instance, design researchers must undergo such a review to apply for ethical clearance for a study.[30] After considering end-users' social and cultural contexts, designers should address the specifics of communication formats.

Semantics enable human beings to order and develop complex mechanisms of communication. Klaus Krippendorff states, "Product semantics is the study of the symbolic qualities of man-made forms in the context of their use and the application of this knowledge to industrial design." If I were to order the semiotic rules of product design and co-design activities under reference, category, and prototype, I would describe each as follows. A reference is a cognitive reference point; category is an ontology or class of things; while a prototype is a grading of examples in a category. Industrial designers communicate semiotic rules or coding during new product development processes through a range of formats from non-verbal gestures to technical documents. They must initially categorize communication forms before reviewing communication models. (See Table 1.)

From the generic, broad characterization shown in Table 1, I chose communication formats with a focus on design specifics conventionally used during new product design processes. Then, I identified five key design methods as conventional for communicating during design process dialogues: 1) sketching; 2) presentation board or visualization; 3) sketch or functional model; 4) role play; and 5) dialogue. I defined forty-one specific communication elements within these formats. In Figure 2, I fit these into a taxonomy of human sensory perceptions—visual, aural, taste, smell, temperature, vibration, haptic or tactile, and body movement.

Table 1. Categorization of language, communication formats, and design delivery format.

	Type	Communication format	Design delivery format
Verbal	Language	voice, spoken language	presentation, interview, focus group, speech, poem
Nonverbal	Visual	written, image (2D)	report, essay, poem, story, technical drawing, schematic, diagram, animation, film, computer-generated image, image collection (mood board)
	Paralinguistic	voice other than language, such as music, tones and pitch	presentation, interview, focus group, speech, song, synthesized noise
	Proxemic	space that is intimate, personal, social and public	presentation, interview, focus group, speech
	Artifact	signs or signals from dress codes, accessories or other body-worn items (3D)	product, clothes, jewelry, hairstyle, body modification
	Chronemic	time and sequencing during communication and transmission	animation, film, speech, poem, story, music, synthesized noise, dance
	Kinesics	whole body movements, gestures, limb movement and sequencing of combined movements (3D)	presentation, interview, focus group, speech, song, dance

Summative Review Findings

Our review of the twenty cases (Box 1) resulted in a number of differences in interpretation. We resolved these quickly by jointly reviewing the material with an eye to locating the exact locations in the texts of the formats in question, shown in an online dataset.[31]

Box 1. The list of twenty cases.

Torrens, George. "Understanding the Product User: The Implementation of a User-Centred Design Approach by Student Industrial Designers when Designing for Elderly and Disabled People." *The Design Journal* 3, no. 1 (2000): 15–30.

Torrens, George, Deana McDonagh-Philp, and Anne Newman. "Getting a grip." *Ergonomics in Design* 9, no. 2 (2001): 7–13.

Torrens, George E. "16 Universal Design: Empathy and Affinity." In *Handbook of Human Factors and Ergonomics in Consumer Products*, edited by Waldemar Karwowski, Marcelo, M. Soares, and Neville, A. Stanton, 233–48. Boca Raton: CRC Press, 2011.

Torrens, George E. "Assistive Technology Product to Universal Design: A Way Forward." *Design for All* 7, no.7 (2012): 182–205.

Torrens, George. "Design for Ageing and Disability at Key Stage 4: An Introduction to the Nature of Designing, Available Teaching Materials and Resources." *Journal of the National Association of Design Education* 2 (1998): 19–35.

Torrens, George E, Jan Hann, Martin Webley, Jo Joy, and Ian. A. Sutherland. "Hand Performance Assessment of Ten People with Rheumatoid Arthritis When Using a Range of Specified Saucepans." *Disability and Rehabilitation* 22, no. 3 (2000): 123.

Torrens, George E., Russell Marshall, John Burkitt, and Graham Kay. "Using Modularity to Produce More Competitive Assistive Technology Products." *Proceedings of the 13th Irish Manufacturing Committee*, edited by M. T. Hillery, 797–804. Limerick: Univesrity of Limerick, 1996.

Torrens, George E., and Helen Newton. "Getting the Most from Working with Higher Education: A Review of Methods Used within a Participatory Design Activity Involving KS3 Special School Pupils and Undergraduate and Post-graduate Industrial Design Students." *Design Technology Education: An International Journal* 18, no.1 (2013): 58–71.

Torrens, George E., and Nicholas C.S. Smith. "Evaluation of an Assistive Technology Product Design Using a Paired Comparisons Method within a Mixed Methods Approach: A Case Study Evaluating Preferences for Four Types of Cutlery with 34 Upper Limb Impaired Participants." *Disability and Rehabilitation: Assistive Technology* 8, no.4 (2013): 340–47.

Torrens, George E., Gavin L. Williams, and Richard Huxley. "Can You Open This Jar for Me Please: A Pilot Study of the Physical Nature of Jar Opening." In *Contemporary Ergonomics 2001*, edited by Margaret A. Hanson, 83–89. London: Taylor and Francis, 2001.

Choi, Young Mi, and Stephen H. Sprigle. "Approaches for Evaluating the Usability of Assistive Technology Product Prototypes." *Assistive Technology* 23, no. 1 (2011): 36–41.

Hyun, Kim K., Sung H. Han, Jaehyun Park, and Joohwan Park. "The Interaction Experiences of Visually Impaired People with Assistive Technology: A Case Study of Smartphones." *International Journal of Industrial Ergonomics* 55 (2016): 22–33.

Kairy, Dahlia, et al. "Exploring Powered Wheelchair Users and Their Caregivers' Perspectives on Potential Intelligent Power Wheelchair Use: A Qualitative Study." *International Journal of Environmental Research and Public Health* 11, no. 2 (2014): 2244–61.

de la Rocha, Fábio R., Guilherme M. Zilli, Daniel Sebben, and Antônio H. de Sousa. "A Case Study on Assistive Technology for Visual Impairment Individuals: Adaptations in Household Appliances." *Journal of Control, Automation and Electrical Systems* 25, no. 2 (2014): 228–36.

Paredes, Hugo, Hugo Fernandes, Paulo Martins, and João Barroso. "Gathering the Users' Needs in the Development of Assistive Technology: A Blind Navigation System Use Case." In *Universal Access in Human-Computer Interaction. Applications and Serices for Quality of Life*, edited by C. Stephanidis and M. Antona, 79–88. Berlin: Springer, 2013.

Shinohara, Kristen, and Josh Tenenberg. "A Blind Person's Interactions with Technology." *Communications of the ACM* 52, no. 8 (2009): 58–66.

Gardner, Lorraine, Lesley Powell, and Magdalen Page. "An Appraisal of a Selection of Products Currently Available to Older Consumers." *Applied Ergonomics* 24, no. 1 (1993): 35–39.

Demirbilek, Oya, and Halime Demirkan. "Universal Product Design Involving Elderly Users: A Participatory Design Model." *Applied Ergonomics* 35, no. 4 (2004): 361–70.

Keates, Simeon, John P. Clarkson, Lee-Anne Harrison, and Peter Robinson. "Towards a Practical Inclusive Design Approach." In *Proceedings of the 2000 conference on Universal Usability*, 45–52. Arlington: ACM: 2000.

Black, Ken, and Doug Williamson. "Designing Inclusive Physical Activities and Games." In *Design for Sport*, edited by Anxo Cereijo Roibas, Emanuel Stamatakis, and Ken Black, 195–224. Farnham: Gower, 2011.

The dataset provides a hierarchy of frequently applied communication formats found in the twenty publications. We grouped the communication formats under the generic titles of dialogue, role play, sketch or functional model, presentation board or visualization, and sketch drawing, and matched these with mechanisms of sensory perception. We chose titles that a layperson will find easy to understand, rather than technically precise terms.

Figure 2 shows potential use, based upon my experiences; while Figure 3 highlights the frequency of times designers employed the same communication formats in the reviewed literature. Figure 3 reveals that the twenty articles cited only twenty-nine communication formats out of forty-one potential modes. Of those, only thirteen formats were used in half or more of the reviewed studies. Not surprisingly, all case studies describe two-way dialogue between individuals, with all but one using functional prototypes. Figure 2 shows that the majority of communication formats were visual or aural, not unusual in an industrial design-focused review of assistive product development. Clearly, a functional prototype would satisfy all sensory input mechanisms. However, in the early stages of a design process, the cost of functional prototype tends to be prohibitive. However, using physical examples of existing products and low-fidelity sketch models is a cost-effective compromise.

Research Process and Resources for Design Practitioners

This investigation calls attention to several points related to literature review and analysis. The speed and accessibility of meta-search engines makes inexpensive literature reviews possible before starting even small-scale commercial design projects. In my experience, the quality of information acquired early in a project has a notable effect on the ability of the final design to satisfy the end-user's needs and wishes. High quality information enhances insights and reduces iteration cycles. In turn, this leads to cost-effective processes of shorter duration for applied researchers and designers.

I have used both thematic analysis and summative content analysis. I find summative content analysis more effective and more cost effective within the context of a short design projects. Although summative content analysis is a relatively crude research instrument, it provides applicable insights into the frequency with which designers use certain communication formats. Moreover, it does not require software to generate more sophisticated interpretations of data. It should prove a useful research tool for design practitioners undertaking a large-scale review of evidence in which the frequency of defined elements may be important.

Conclusion

This study generated useful insights and resources for design practitioners and researchers working in the field of assistive product design. The literature review highlighted the challenge of reduced communication opinions due to the compounded constraints of culture, language, and impairment.

The more constraints that circumstances place on the dialogue among end-users, stakeholders, and designers, the fewer communication options may be appropriate.

The review also highlighted the need to review the social and cultural aspects of niche markets to ensure that designers follow appropriate etiquette and social protocol when undertaking participatory design with end-users. Designers may better understand context, belief systems, values, and specific language in formulating an initial approach to any participatory research or a co-design project after
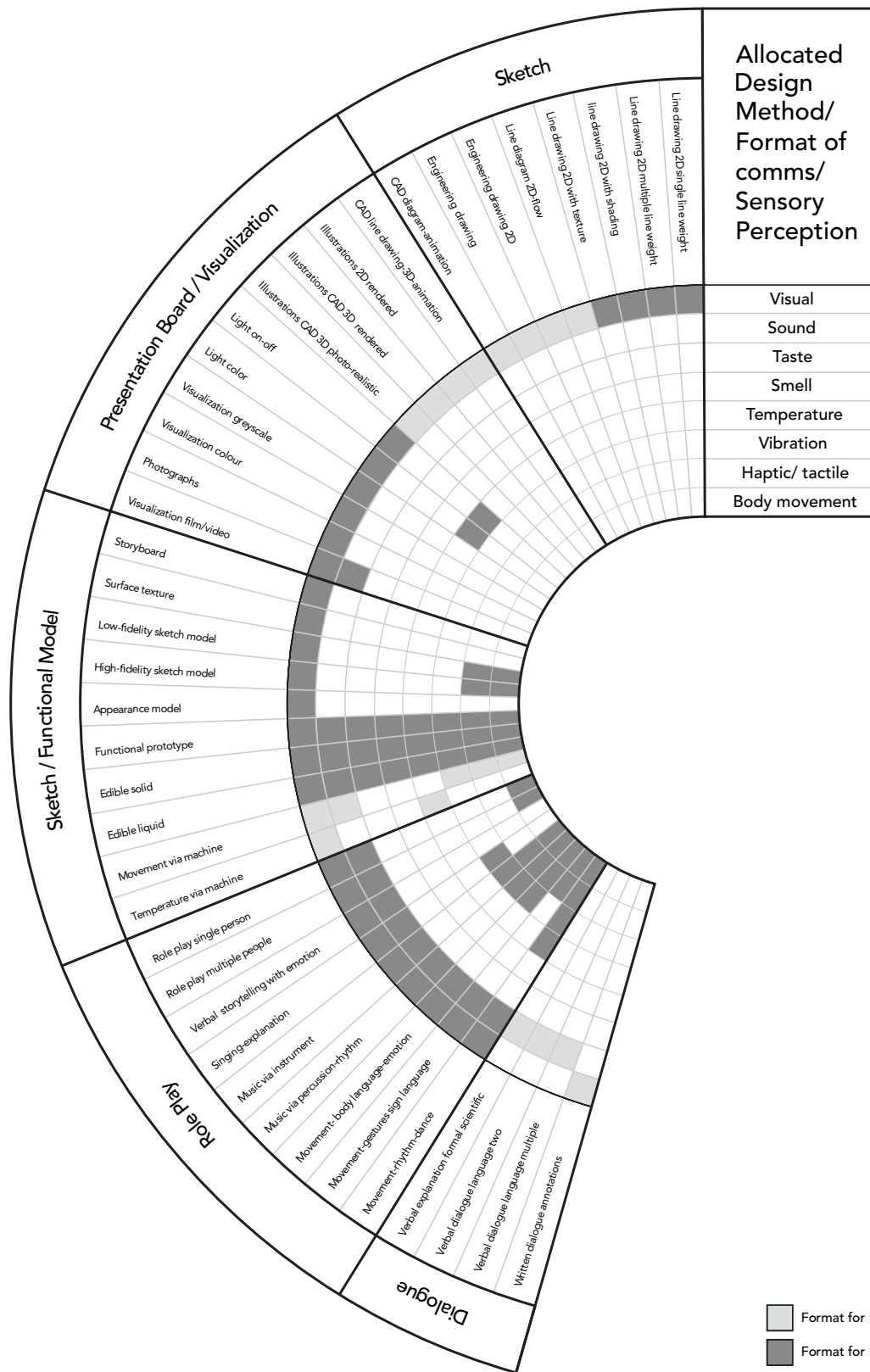
Figure 2   Potential use of communication formats in relation to mechanisms of sensory perception. Copyright © 2017 George Edward Torrens.
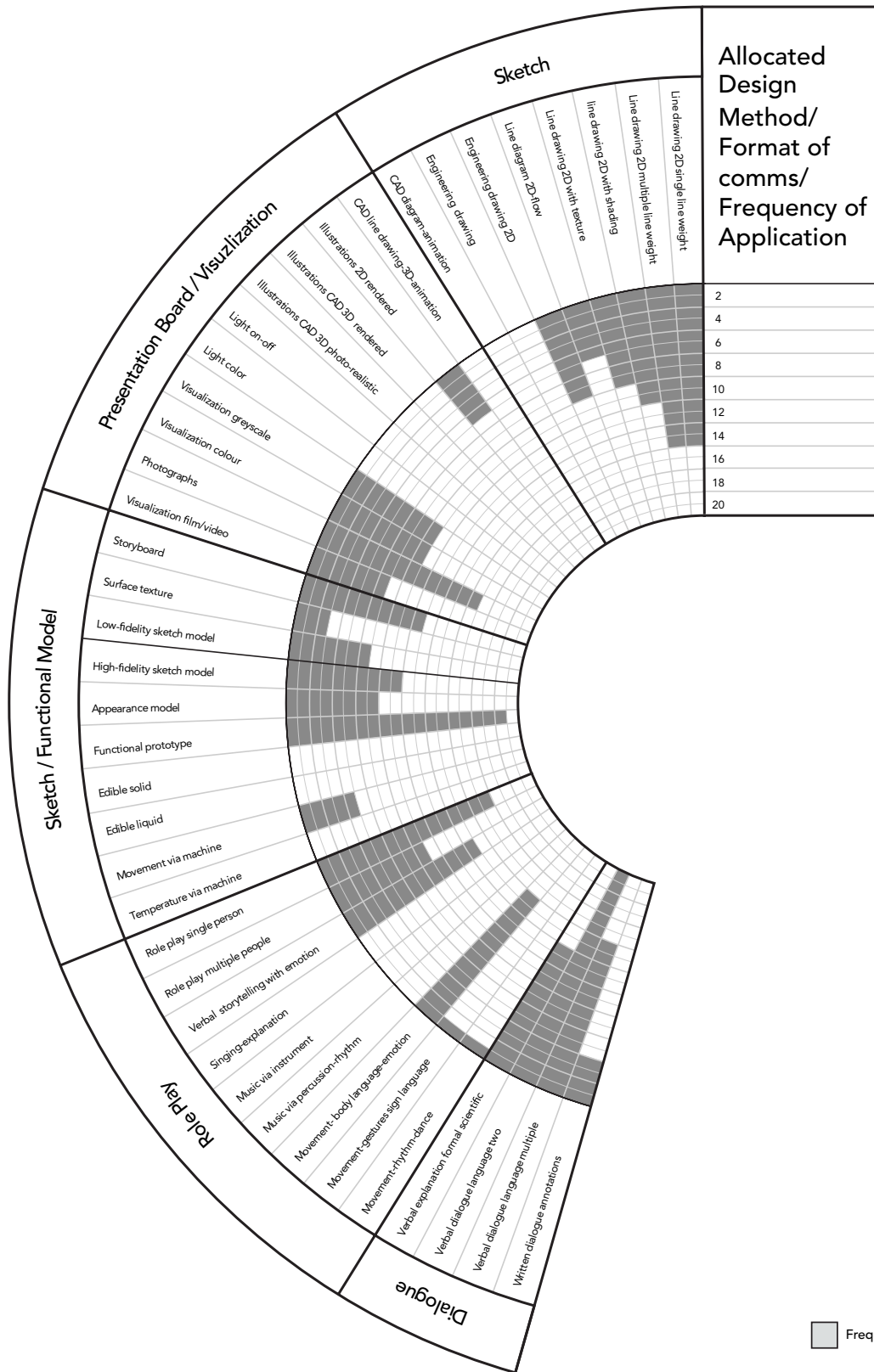
Figure 3 **Frequency of communication formats in the reviewed studies. Copyright © 2017 George Edward Torrens.**

The chart labels, reading around the fan, include:

Sketch:
- Line drawing 2D single line weight
- Line drawing 2D multiple line weight
- line drawing 2D with shading
- Line drawing 2D with texture
- Line diagram 2D-flow
- Engineering drawing 2D
- Engineering drawing
- CAD diagram-animation

Presentation Board / Visuzlization:
- CAD line drawing-3D-animation
- Illustrations 2D rendered
- Illustrations CAD 3D rendered
- Illustrations CAD 3D photo-realistic
- Light on-off
- Light color
- Visualization greyscale
- Visualization colour
- Photographs
- Visualization film/video

Sketch / Functional Model:
- Storyboard
- Surface texture
- Low-fidelity sketch model
- High-fidelity sketch model
- Appearance model
- Functional prototype
- Edible solid
- Edible liquid
- Movement via machine
- Temperature via machine

Role Play:
- Role play single person
- Role play multiple people
- Verbal storytelling with emotion
- Singing-explanation
- Music via instrument
- Music via percussion-rhythm
- Movement- body language-emotion
- Movement-gestures-sign language
- Movement-rhythm-dance

Dialogue:
- Verbal explanation formal scientific
- Verbal dialogue language two
- Verbal dialogue language multiple
- Written dialogue annotations

Allocated Design Method/ Format of comms/ Frequency of Application

2
4
6
8
10
12
14
16
18
20

Frequency of Application

preparing appropriate supporting communication formats and materials. The taxonomy suggests that three-dimensional, functional products and prototypes are the most effective communication mode for all types of impairment. Nevertheless, these are the most expensive option. Effective compromises in participatory design or co-design exercises include using existing products, low-fidelity models, or mock-ups with an appropriate level of function.

While the taxonomy Figure 2 defines each impairment in isolation, the reality is that many people living with disability have more than one impairment (compound impairment). Researchers and design practitioners must consider this possibility when considering appropriate etiquette and choosing communication formats. However, the taxonomy may prove useful to design practitioners and researchers undertaking participatory design or co-design with any individual, not just those living with an impairment or disability. Designers may also apply the taxonomy to interactions with people from different cultural backgrounds, people who speak a different language, or people of a different gender or age groups.

The review yields a taxonomy of dialogue formats matched to forms of sensory impairment. It provides a template for how to approach working with people living with disabilities.

The taxonomy has the potential as a useful heuristic device. It is part of Usability-NET,[32] and it is therefore freely accessible to design practitioners and design researchers.

Enhancing the future of industrial design and product design requires us to move from measuring a product's success through market sales alone as the sole outcome. Isolating aspects of design processes, testing theories, and then combining them to create more complete products and services has numerous advantages. These include more effective definitions of end-user needs and desires; reduced investment risks for new products or services; improved audit trails; and more economical, evidence-based decision-making leading more quickly to effective design solutions. The choice of communication formats provides a good example of how we may optimize a design process component and validated it in practice.

The issue of efficacy in the application of communication formats requires further investigation. This investigation should include testing and evaluation of the effectiveness and economy of communication formats with different combinations of dialogue constraints. We also need to engage in debate about how best to categorize applied communication formats and use them to optimum benefits in design processes. The claim made in this article concerning definitions of dialogue and communication formats require further study, refinement, and expansion to ensure efficacy in practice.

Acknowledgments