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A Study of Roles and Collaboration in the Development of Assistive Devices for People with Disabilities by Clinical Experts and Design Experts

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This study is part of a research program promoting the expertise of professional manpower in the Korean assistive device industry. Based on interviews with clinical and design experts, the authors discuss the advantages and difficulties of this collaboration, and suggest ways in which it might be improved. They discuss the roles of clinical and design experts, and consider the product components involved in the development of assistive devices. The roles of clinical experts and design experts have common elements in that both groups take a human-centered approach to product development. Design and clinical experts should collaborate further in the development of assistive devices, and this should lead to the shortening of product development time and to user needs being better met in new products. Research exploring guidelines for collaboration is needed in order to solve problems and difficulties arising from the convergence of these two areas of expertise.

roles of specialists; collaboration; assistive devices; human-centered design

1 Introduction

1.1 Background and Purpose

Assistive devices and technologies are those whose primary purpose is to maintain or improve an individual's functioning and independence, to facilitate participation, or to enhance overall well-being. Examples of assistive devices and technologies include wheelchairs, prostheses, hearing aids, visual aids, and specialized computer software or hardware that increase mobility, hearing, vision, or communication capacities (WHO, 2017).

According to a survey of the assistive device industry in Korea (Kweon & Park, 2012), 64% of companies active in that industry are private enterprises rather than corporations, and more than 40% have capital of less than US$ 44,610. Although almost 60% of the respondents indicated that they were investing in research and development, the scale of their efforts and the methods they

employed were variable. They reported difficulties in creating the systems necessary to manufacture assistive device, procuring operating funds, financing technology development, securing a place in the domestic market, and exploring overseas markets. Apparently as a result, the Korean assistive device industry is quite small and lacks the required infrastructure and manpower. In general, further research into product development work using limited numbers of people is necessary; there is also a specific shortage of research on the needs of assistive device makers and on how they might assemble a workforce with the necessary expertise.

Choi et al. (2006) note that companies involved in assistive device production often have little awareness of the existence of AT (Assistive Technology) experts. As a result, it is difficult for AT companies to deploy research and development in order to develop the domestic market or to build a strong global position. A pool of trained professional AT manpower will not emerge if jobs are not available. A multidisciplinary approach involving occupational therapists, physiotherapists, audiologists, and other rehabilitation experts is necessary to understand the levels, types, and functional characteristics of disabilities and to meet the needs of people with these disabilities.

In this study, the authors regard clinical and design experts as fundamental to assistive device development. Both groups have roles to play in product development, in bridging the gap between humans and technologies. However, there are differences in the background knowledge and approaches of these two expert groups—that is, clinicians and design experts—and, consequently, there will be differences in their roles.

The authors of the present study first discuss why collaboration between clinical and design experts is necessary, and identify ways to facilitate this collaboration. Second, they examine the commonalities in, and the differences between, the roles of these two expert groups. Third, they analyze the product components that both groups employ in the development of assistive devices. Through this approach, the authors intend to promote collaboration and increase the efficiency of research and development relating to assistive devices.

1.2 Method and Scope

This study uses the analysis of expert interviews as a qualitative research tool. Research of this kind reconstructs social situations or processes in order to build knowledge in a sociological way. Interviews provide researchers with specific knowledge from participants in the specific situations and processes under examination. In this research, interviews were semi-standardized; although the interviewer's role was structured by a pre-determined questionnaire, each interviewee was free to answer questions in his or her own way (Gläser and Laudel, 2009).

Six experts were interviewed using the four question types proposed by Krueger and Casey (2009): opening questions, introductory questions, key questions, and ending question. Key questions related to the interviewees' careers and roles in assistive device development, their expertise in assistive device development, their perceptions of the advantages and disadvantages of collaboration, the product components they considered most important, and the HAAT model of assistive technology production. To facilitate analysis, all interviews were recorded, with the consent of those involved. Two authors worked on each interview, to agree and analyze its content. The transcribed contents were categorized according to themes observed among the words, contexts, emotional expressions, and actual experiences reported. Based on the results that emerged, the authors debated: the necessity, merits and difficulties of collaboration; how to improve collaboration; a definition of the roles of clinical and design experts in the development of assistive devices; and the product components that each expert considered crucial to the development of assistive devices.

Three clinical experts and three design experts were selected. Each had more than five years' experience in collaborating with experts from other fields in assistive device development. Clinical specialists were limited to occupational therapists who developed assistive devices and services. Assistive technology is one of the powerful frames of reference available to occupational therapists

(Jang, 2005),so occupational therapists are typically more associated with assistive technology than other clinical specialists. Interviewees are described in Table 1.

Table 1 Information on Subjects.

Division	C1	C2	C3
Highest degree and major	Ph.D. in Occupational Therapy	Master's in Ergonomics Therapy	Ph.D. in Health Science
Field experience	5 years	8 years	5 years
Details of assistive device development project undertaken collaboratively	Eye movement tracking mouse: a free development and dissemination project for ALS patients	Car seat development project for children with disabilities	Development of low-level exercise equipment for stroke patients
Division	**D1**	**D2**	**D3**
Highest degree and major	Ph.D. in Design	Ph.D. in Design (to be completed)	Ph.D. in Design
Field experience	More than 10 years	6 years	11 years
Details of assistive device development project undertaken collaboratively	Universal design guide for the elderly	Walking assistance robot designed for the elderly	Walking rehabilitation equipment for stroke patients

The research structure of this study is shown in Figure 1.

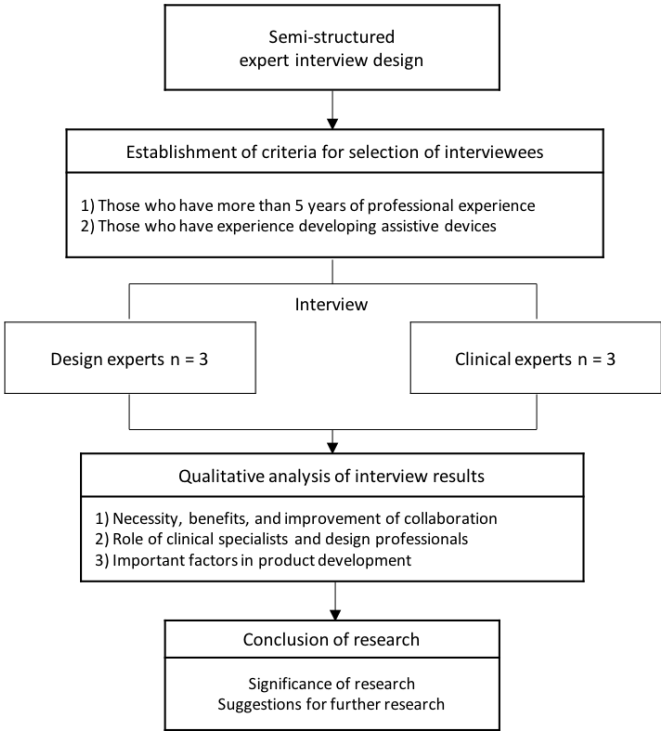

Figure 1 Research Structure.

2 Theoretical Background

2.1 Clinical Experts

2.1.1 Occupational Therapy and Occupational Therapists

The purpose of occupational therapy is to allow people with disabilities to live with the best possible function in relation to the physical, social and cultural aspects of life. Medical science provides the

theoretical background for occupational therapy. For this reason, the occupational therapist must understand, from a medical point of view, theories of disease, injury and functional limitation resulting from a disability. He or she provides therapy to reduce the limitations on daily living caused by these limitations. The role of an occupational therapist, therefore, is to analyze the activities of the subject, to evaluate their function, to train the subject in an environment where ability is maximized, and to select technologies appropriate to the subject's function (Pedretti & Early, 2001).

2.1.2 Theoretical Perspective of Occupational Therapists

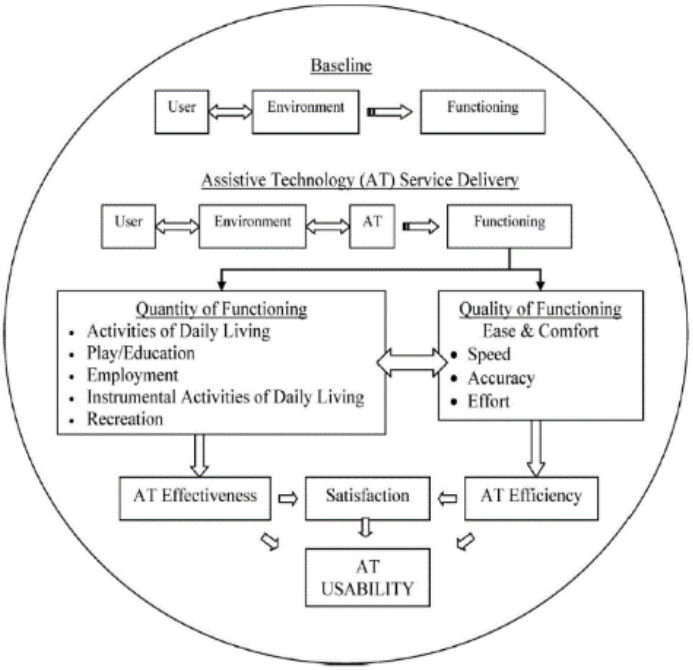

Figure 2 The relationship between user functioning and AT usability. source: Arthanat et al., 2017

Functional limitations due to illness cause restrictions on participation in economic activities, education, play and daily living. Of the various intervention methods available, the application of assistive devices is seen as the best approach to overcoming functional limitations. Thus, when assessing the usability of an assistive device, the occupational therapist assesses the quantitative and qualitative recovery of function, as shown in Figure 2, to determine usability.

2.2 Development of Assistive Devices

2.2.1 Assistive Devices and Usability

The rehabilitation paradigm for people with disabilities is shifting from a treatment-oriented approach towards strategies that combine rehabilitation therapy and technology. From a series of attempts to overcome the limitations of rehabilitation, the use of technology has emerged as playing an important role in improving the accessibility and convenience of the daily and social lives of people with disabilities (Lee et al., 2012)

In one survey (Jung et al., 2009), 43% of respondents who had bought an assistive device themselves said that they did not use it because it was inconvenient. Respondents also said that the devices 'do not help me with what I need' (14.3%) and 'are ill-suited to my needs, preferences, and lifestyle' (14.3%). In essence, a major factor in the non-use of assistive technology devices is lack of usability. When the respondents were asked about the main reason for choosing their assistive devices, 38.8% answered 'efficacy,' 26.5% 'comfortable use,' and 8.3% 'safety.' The results of this study, therefore, suggest that the usability of an assistive device is also an important determinant of purchase decisions.

Unlike other consumer products, an assistive device is used by someone with a disability who has physical and functional discomfort. In addition, an assistive device differs in that it replaces or supplements the physical functions of the user. In contrast with medical devices, it is necessary to consider the complex context of the daily activities with which the user is in need of assistance. Therefore, assistive devices—a daily necessity for people with disabilities—need to be studied in terms of usability, considering the user, the context, and the environment (Kim, Chae & Kweon, 2017).

2.2.2 The Status of the Korean Assistive Device Industry and Supply

In many respects, the Korean assistive device industry is limited by its small size. Its import-oriented distribution structure has prevented the industry from becoming self-sufficient and competitive (Kweon & Park, 2012). The total government budget for the support of assistive device research and development, for the five years from 2011 to 2015, was about US$ 7.4m. A study of the government's support and activation plan for assistive devices for people with disabilities in Korea points out the lack of support for commercialization, which it links to the problem of inadequate support for national research and development. While important fundamental technologies exist, they are not yet being properly developed. Attempts at commercialization, therefore, have proved problematic (Korea Disabled People's Development Institute, 2016), resulting in dependence on imports rather than on domestic devices. Korean research and development needs to result in commercially available products.

In Korea, people with disabilities purchasing assistive devices benefit from financial support from the government as follows: 90% of the purchase price—which is capped—is offered by the government, with the remaining 10% of the expense borne by the user. For example, the maximum amount the government offers towards powered wheelchairs is US$ 1,900. If the actual purchase price of the product is US$ 18,500, only 90% of the US$ 1,900 maximum is provided through government support. In reality, therefore, financial support is very small, owing to the difference between the real cost of an assistive device and the government's upper limit. In addition, the list of assistive devices for which financial support is available is very limited, leaving many important products that have to be purchased at the personal cost of the person with a disability. This limited support for the purchase of assistive devices has caused the burden on people with disabilities to increase, in part because the government's policy has not kept up with market changes or changes in individual needs (National Health Insurance Service, 2016).

3 The Necessity and Benefits of Improving Collaboration

In the interviews, both clinical and design experts said cooperation between their two disciplines is necessary in the development of assistive devices. Both groups focused on applying the characteristics of people with disabilities to a product, and concentrating on the factors that enable people with disabilities to make good use of their products. However, since each expert offered a somewhat different point of view, it appears necessary for cooperation to begin in the early stages of development. The clinical experts considered the functional aspects of a given product mainly in relation to the characteristics of its users, while the design experts primarily considered the product's usability aspects. Table 2 shows the responses to the question about the need for collaborative work.

Table 2 The need for collaborative work.

Division	C1	C2	C3
Clinical expert answers	[It is] needed. Clinical experts have a lot of knowledge about rehabilitation and disability. However, commercializing technologies through product development is the strength of design experts. Each expert's perspective is different. From the beginning of the development process, the participation of the two experts seems to offer the prospect of greater efficiency.	I think it is necessary. The results of collaboration should enable a technology to be applied more effectively to the human user. Therefore, I think that clinical and design experts need to complement each other in order to develop human-centered products.	It is absolutely necessary. The roles of clinical and design experts are different: the clinical expert provides user information; the design expert visualizes actual ideas.
Division	**D1**	**D2**	**D3**
Design expert answers	I think it is necessary. Design experts are well aware of the technologies involved in a product, but they need a clinical expert to better understand the user.	[It] goes without saying. Clinical experts are very helpful in field work because they are familiar with the details of the story and of the situation.	[It's] needed. Designers can't make medical devices using a generic product development process. The experience of clinical experts who are familiar with the characteristics of people with a disability is very important to understanding their needs.

Questions and answers concerning the benefits of collaboration are shown in Table 3.

Table 3 The benefits of collaboration.

Division	Interview questions	C1	C2	C3
Clinical Experts	What do you see as the benefits of design expert participation in the development of assistive devices?	Discovering new perspectives and learning how to approach the process. Clinical experts are not focused on development (they focus on treatment, improvement, and maintaining function). I was able to see the process from the designer's point of view, which was more focused on product development.	Considering sales in assistive device development process. Commercialization is easier with the participation of design experts (and it results in time reduction). Users' aesthetic needs as well as their functional needs are met.	Visualization of the product in its realizable form is possible. The implementation of feedback is faster, and the progress of the work, therefore, is easier.
	How did collaboration with design experts help you improve your skills when developing assistive devices?	As our understanding of design terminology increased, communication with designers became clearer than before.	I was able to learn about important development factors (e.g., intuitive usability) from studies in product development.	I acquired design knowledge, and learned the language used by design experts relevant to each situation. Having experienced this different perspective,

				coordinating differing opinions became smoother.
Division	**Interview questions**	**D1**	**D2**	**D3**
Design Experts	What do you see as the benefits of clinical expert participation in the development of assistive devices?	They raise important issues related to users. They provide useful guidance for product development by offering helpful explanations of certain problems. During our collaboration, I gained information and knowledge about the context in which I was working.	On-site communication, such as interviews, makes for a tighter connection with the product users.	It is like creating a shell with no function, when only designers are involved.
	How did collaboration with clinical experts help you improve your skills when developing assistive devices?	[I] learned a lot from the presentation of research undertaken with users.	It is very helpful in this field. I learned how to use literacy data in practice, and how to explore it in order to gain deeper insight into the task.	Understanding the characteristics of the patients, and drawing up details of their short-term requirements.

The difficulties encountered in collaboration, and the areas that need to be improved or corrected in the course of collaboration, are shown in Table 4.

Table 4 Difficulties and necessary improvements in collaboration.

Division	**Interview questions**	**C1**	**C2**	**C3**
Clinical experts	What difficulties have you encountered when involving design experts in the development of assistive devices?	As the number of participants in the development process increases, the time and cost involved also increase. There is also the burden of maintaining control, communication, and collaboration among so many stakeholders.	It is time-consuming to add a design stage in the product development process, and communication is not always smooth.	Confusion about differences in terminology can arise, sometimes resulting in unintended consequences.
	How can the interactions among groups of experts be improved or modified to facilitate better collaboration?	We need to respect each other's expertise. Understanding each other's scholarship is important. Clarity of responsibilities is also required of each expert.	Increasing opportunities for collaboration will enable better communication among experts.	There is a possibility of friction emerging among experts of different disciplines.
Division	**Interview questions**	**D1**	**D2**	**D3**
Design experts	What difficulties have you	Basically, the understanding of	The terms that were used by design experts	In the prototype phase of working, the clinical

	encountered when involving clinical experts in the development of assistive devices?	design and decision making is different at the development stage. Conflicts can arise when colleagues persist in emphasizing their own understandings.	were not always accessible to clinical experts.	expert receives a lot of feedback. This increases the intensity of the workload.
	How can the interactions between groups of experts be improved or modified to facilitate better collaboration?	We need an open attitude in order to communicate well. Also, from the start, stakeholders should be involved in the process, so that their willingness to participate is maintained.	It is necessary to meet from the beginning. If I had a basic manual showing when to meet and talk, it would make things easier.	We need some collaborative guidelines so that we can apply everyone's ideas objectively and move in the right direction.

A common opinion was that a key advantage of collaboration was a shorter development time, but that confusion around terminology was a clear disadvantage. Clinical experts said that development time was shorter because the process of visualization of ideas became smoother; the design experts perceived that a better understanding of the user's needs similarly allowed a shorter timescale.

Although both clinical and design experts say that collaboration is necessary, it is rare that experts actually collaborate on assistive device development projects. In addition, even when both clinical and design experts are involved, there are few cases where they collaborate from the very first stage of development. The Korea Disabled People's Development Institute notes that the assistive device industry depends on imports and that the research and development of products are insufficiently commercialized in Korea. Domestic design and clinical experts should collaborate in the development of assistive devices, which should lead to a shortening of product development time and users' needs being met more accurately in new products. This will increase the merchantability of new products and promote the commercialization of research and development output. It is necessary, therefore, to explore how cooperation between these two expert groups can be encouraged. Based on an understanding of the roles of the two expert groups defined in this research, moreover, it is necessary to study the manpower requirements of the processes in assistive device development projects. There can be a lack of understanding and respect for the expertise brought by counterparts from another discipline, and communication difficulties arising from differences in language use can also arise. In order to improve collaboration, it is necessary for those involved to learn more about the process of collaboration. In particular, it is necessary to clarify the perspectives and roles provided by each discipline, to improve communication by learning about relevant terminology, and to facilitate the interaction of experts in the development process. Together, this suggests the need for guidelines on collaboration itself.

4 The Role of Clinical and Design Experts

Table 5 lists questions and answers regarding the role of clinical and design experts, as seen by the clinical experts.

Table 5 Expert roles as seen by clinical specialists.

No.	Interview questions	C1	C2	C3
1	What do you think is the role of clinical experts in the development of assistive devices?	Building a foundation for development based on theoretical and practical knowledge of, and experience with, the user.	Predicting problems with the assistive device based on knowledge of disabilities. Applying newly developed assistive devices to people with disabilities, and training them as users.	1. Determining the object, purpose and appropriate function of an assistive device. 2. Judging whether it is appropriate after development.
2	What do you think is the role of design experts in the development of assistive devices?	Drawing out areas that could be missed during development, such as specifying and segmenting particular needs, and typifying product composition.	Aesthetics and functionality of products.	The role comprises visualization, specification, and making tangible the clinical experts' summaries.
3	Do you think that experts from both areas have a common role?	Analyzing, observing and evaluating users (people with disabilities).	A human-centered approach to product development as a basic first step.	Involvement in the development itself provides a common role.
4	What do you think is the positive impact of your involvement in your assistive device development project?	Providing knowledge and know-how about the actual lives of people with disabilities.	Obtaining and providing data based on an understanding of the subject (people with disabilities, and the elderly). Highlighting improvement points in relation to actual subjects. Delivering information in terms easily understood by other experts.	In working with the assistive device, I can find practical problems and help solve them. Also, I am able to judge the results of any alternative solution devised.

The common role of clinical and design experts in the development of assistive devices is to analyze and evaluate users, to think about ways in which devices are used, and to fill in the gaps between humans and machines. The role of the clinical experts in the development of assistive devices was identified as defining the objects, objectives and appropriate functions of the assistive devices, based on an understanding of the disability. In addition, clinicians are able to judge whether an assistive device is suitable and to predict problems. The role of design experts in the development of assistive devices was identified as the segmentation of ideas, realization of actual products, visualization, and determination of technological possibilities. It is also evident that the role of design experts was to commercialize ideas and to deal with technical aspects of the new products.

The 'evaluation' provided by a clinical expert is an evaluation of the functional status of the user (a person with a disability) and of whether the user's function is recovered when the product is deployed. This term is used differently when a design expert 'evaluates' the usability of the product.

Table 6 shows questions and answers regarding the roles of clinical and design experts as seen by the design experts.

Table 6 Expert roles as seen by design experts.

No.	Interview Questions	D1	D2	D3
1	What do you think is the role of clinical experts in the development of assistive devices?	It depends on when they are brought into the development process. Their participation helps to understand the user.	Providing information about the characteristics of the subject (elderly persons) and their usage status. Determining whether the result is usable.	It is important for clinical research to maintain consistency so that it can proceed according to a clear protocol. Consistent clinical studies help in identifying problems.
2	What do you think is the role of design experts in the development of assistive devices?	Providing solutions to issues and moving projects towards their resolution.	Consideration of usability. Detailed knowledge of product materials and of design elements.	They deal with design, interview analysis, clinical research, usability evaluations, testing and compliance with FDA requirements. They catch problems in products that appear during clinical studies.
3	Do you think that experts from both areas have a common role?	End-users are important to both groups, but I think that roles and positions of each group will be different in each development process.	An approach which emphasizes the user's point of view.	The identification of problems and implementation of improvements through clinical research. Solving problems so that devices can provide optimal functionality in the field. (Clinical experts have responsibility for the functional part; design experts, for the usability part.)
4	What do you think is the positive impact of your involvement in your assistive device development project?	When I was conducting a field survey, I actually looked through the situation analysis to see what was inconvenient and what the problems were.	Basically, improving the design of the external part: usability, aesthetic aspects, etc.	End products that are developed to match as closely as possible the original purpose. Increased marketability with clear results. Products that fully reflect usability, accessibility, worries about maintenance, and worries about stakeholders. Products that are attractive for export.

The design experts agreed that understanding the user was a common role of the two expert groups, and that a common starting point was to think from the user's point of view. In addition, they said that both groups should use clinical studies to elucidate problems and improvement points so that problems could be solved in ways that allowed equipment to perform optimally. The role of clinical experts was seen as providing users information and resolving issues. The role of design experts was said to be enhancing the completeness of products, by considering product-user interactions and by upgrading products as a whole.

Table 7 summarizes the roles of clinical and design experts resulting from the interviews.

Table 7 The roles of clinical and design experts.

Division	Clinical experts	Design experts
Common roles in the development process	Human-centered approach to product development	
Differences in background knowledge	Theoretical knowledge and experience of functional limitations of disabilities	Understanding product components, visualization technology
Differences of perspective on humans	Focus on people and activities (↓); a vertical understanding based on anatomy	Focus not only on people but on things and environments (↔); a horizontal understanding of interaction
Differences of perspective on usability	Consider the purpose, function, and safety of the product. Help user restore limited functionality by using the product	Consider physical, aesthetic, and contextual usability, and factors such as product, usage environment, and stakeholders
Role in early stages of development	Identifying the characteristics of the user to be reflected in the product	Precisely defining user needs and converting needs into solutions
Role in later stages of development	Judging suitability and forecasting problems when using assistive device with people with disabilities	Consideration of details related to use, visualization, and tangible benefits

A clear difference in perspective emerges in Table 7: clinical experts look first at 'the disabilities of the person' while design experts look at 'how a user will interact with a device.' In addition, differences in defining 'usability' emerge: clinical experts consider an assistive device as 'a tool to replace or complement a physical function' of a person with a disability, while design experts regard the assistive device as 'a product for daily living' used by a person with a disability. In Table 9, the authors of this study show how these viewpoints change when considered in light of the HAAT model of the roles of the two expert groups.

Figure 3 shows the differences in the viewpoints and roles of clinical and design experts in relation to assistive device development, summarizing the results presented above. Clinical experts think from person to product and from product to person; design experts think about the interaction of people with products. Clinical experts use an understanding of the functional characteristics of the user to generate product ideas and to evaluate the product in the field; design experts work to enhance the completeness of the product based on the interactions between the product and the user.

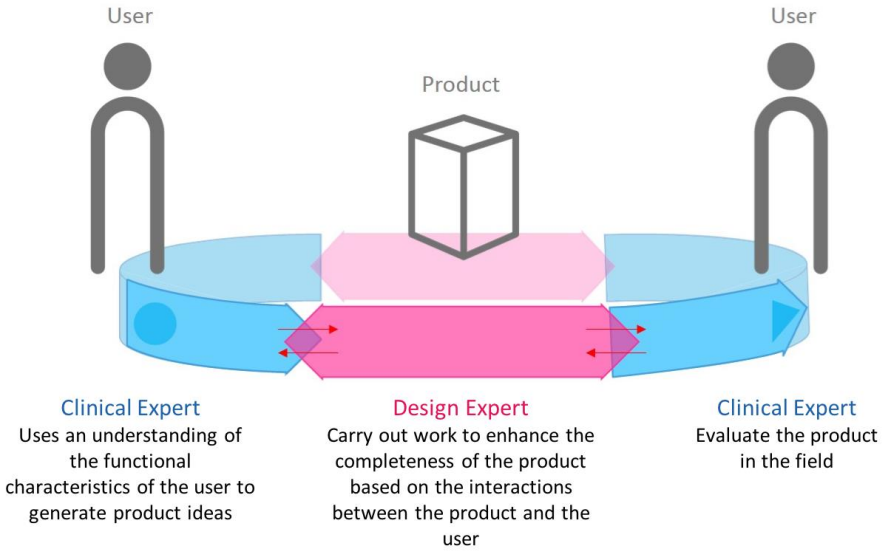

Figure 3 Differences in viewpoints and roles of development process.

5 Considerations in Assistive Device Research and Development

5.1 Product Components

The authors asked each expert to list product components in order of the priority. The answers are shown in Table 8, below. The product components are aesthetics, motivation, function, ergonomics, mechanism, structure, production, economics, and presentation (Archer, 1965).

Table 8 Product components.

Order of priority	C1	C2	C3	D1	D2	D3
1	Function	Economics	Ergonomics	Motivation	Ergonomics	Ergonomics
2	Economics	Function	Function	Function	Function	Mechanism
3	Ergonomics	Ergonomics	Mechanism	Ergonomics/ Structure	Aesthetics	Function
4	Mechanism	Motivation	Aesthetics	Aesthetics	Presentation	Aesthetics
5	Presentation	Structure	Motivation	Production		Economics
6		Production		Economics		Production
7		Presentation		Mechanism		
8		Aesthetics		Presentation		
9		Mechanism				

All six experts gave higher priority to function and ergonomics, with two clinical experts more likely to consider economics in addition to these first two components. Functional and ergonomic factors are clearly important because of the characteristics of the users (people with disabilities) and of the context of use (as the products are intended to enhance the users' functional capabilities and convenience in the context of daily living activities). In addition, the reason that clinical and design experts shared this common emphasis on function and ergonomics was not only because they understood the characteristics of the users and of the context of use, but also because they have a shared aim to reflect research undertaken with users of the product.

Economics was selected as a high priority factor by two clinical experts. According to a survey on people with disabilities in Korea (Korea Institute for Health and Social Affairs, 2014), the salaries and levels of economic activity of people with disabilities living in Korea are less than 70% of those earned by people without disabilities. In addition, the domestic assistive device service law provides different services according to a person's level of disability. For these reasons, the majority of Koreans with disabilities face considerable financial hurdles when purchasing assistive devices. From the viewpoint of the clinical specialist using assistive devices in the field, therefore, economic factors that determine price are very important.

5.2 Details of the HAAT model

The HAAT model employs four elements to consider assistive technology: Human, Activity, Assistive Technology, and Environment and Context; the first three elements must be integrated (see Figure 4, taken from Cook & Polar, 2014).

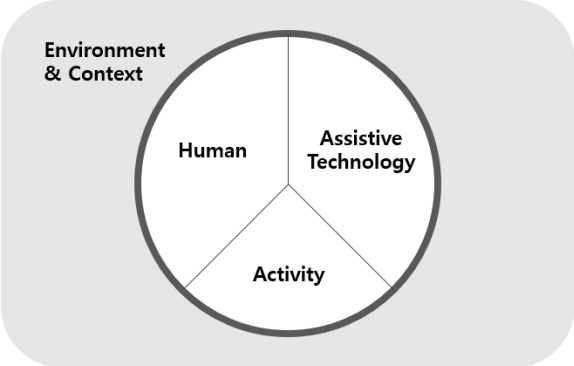

Figure 4 The HAAT model. source: Cook & Polar, 2014

The HAAT model deals specifically with the AT field, but many similar models exist in the field of design (e.g., AEIOU: activity, environment, interaction, object, user). Looking at how the two expert groups handle the four elements of the HAAT model, therefore, we can see similarities and differences in their perspectives. In this study, each expert was asked to explain in his or her own words which subcritical items of the HAAT model he or she considered important in the development of assistive devices (Table 9).

Table 9 Component Details in the HAAT model.

No.	Component	Clinical experts	Design experts
1	Human	Physical characteristics: diagnosis (degree of damage), musculoskeletal structure and function level. Psychological characteristics: emotional state. Cognitive characteristics.	Physical characteristics: level of function, range of motion, human scale. Psychological characteristics: taste, aesthetic. Cognitive characteristics: cultural differences.
2	Activity	Activities of daily living, learning, work, leisure. Activities needed for independent living .	Behavior, posture requirements, life pattern. Activities needed for independent living.
3	Assistive Technology	How well it can be applied to a user, whether it is a technology that invites rejection or is a feasible technology. Safety, effectiveness, efficiency, satisfaction.	Requirements of technology according to life pattern (e.g., battery charging time). Accessibility, usability. The obtrusiveness of the technology.
4	Environment and Context	Considering where to use assistive devices (home, school, work, social/leisure activities, transportation), price (economy).	Considering where to use assistive devices, inside/outside, whether used alone or with multiple people, time (day/night).

The details of the HAAT model described by clinical experts are focused on product function, and based on disability and independent daily living activities. Design experts focused on users, on overall elements, and on how the context in which the products are used affects the product interface.

In relation to the human factors of the HAAT model, the clinical experts considered the diagnosis, the musculoskeletal structure, and the functional level to be among the most important physical characteristics. The design experts considered range of motion and human scale as the physical characteristics they considered most important. In relation to the activity element, the clinical experts referred to the activity type, while the design experts chose behavior, attitudes, and patterns and types of activities. In relation to assistive technology, the clinical experts cited acceptance or rejection of the technology when applied in the field, and also highlighted safety and

usability. Design experts chose technological requirements and usability in relation to life patterns. These differences suggest that clinical experts consider direct responses (psychological/physical) when using technology with humans, while design professionals see the congruence of context and technology. Here again, clinical experts stressed price in environment and context.

6 Conclusions

It is evident, as a result of the one-on-one interviews, that the roles of clinical and design experts have common elements, in that each group takes a human-centered approach to product development. This is especially clear when compared with, for example, the role of an engineer. An engineer focuses on the operation of a product, whereas clinical and design experts focus on its use. However, there are differences in the 'user-centered' approaches employed by the two groups. There are differences in background knowledge, differences in attitudes toward users, and differences in perceptions of the usability of assistive devices; thus differences in roles occur between the early and the later stages of device development (see Tables 7, 9; Figure 3). This study does not provide role comparisons for all stakeholders in the development of assistive devices, so further research is certainly required.

The implications of this study are as follows. There are few, if any, qualitative studies on collaboration between clinicians and designers of assistive devices; the present authors address this lack of qualitative analysis using a methodology that employed one-on-one interviews. Second, assistive technology is a field in which new technologies and equipment necessary for people with disabilities are developed; this study confirms the necessity of multidisciplinary research and development for assistive devices. Third, the authors have identified differences of view and role that should be addressed in collaborative research by expert groups in different fields. Fourth, collaborative research between design and occupation experts is an exemplary research model for the kinds of intervention research that should be done before an assistive device is turned over to the person with a disability. Intervention research tests consumer responses to existing commercialized technology, finds problems that occur as the technology is used, and revises and re-develops the technology.

This is an initial study of roles and collaboration in the development of assistive devices by clinical and design experts, and further systematic study of these groups is required. As noted, research that includes other experts (especially engineers) is also necessary in order to understand the multidisciplinary context more completely. Third, the authors have recognized and defined various differences in the viewpoints and roles of the two expert groups. Based on these findings, research on collaboration models and guidelines should follow. In particular, guidelines for collaboration are urgently required in order to solve problems and difficulties that emerge when expert groups converge. Fourth, there is a need for further research into the ways in which research on this kind of convergence can be disseminated in the field of assistive device production.

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