MASTER

The connected dance chair
a study into the psychological impact of using an online, automated wheelchair for dancing

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THE CONNECTED DANCE CHAIR: A STUDY INTO THE PSYCHOLOGICAL IMPACT OF USING AN ONLINE, AUTOMATED WHEELCHAIR FOR DANCING

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Wheelchair users may face physical and psychological challenges due to the difficulty to leave their houses and join social activities especially in countries with fewer facilities for wheelchair users. In addition, wheelchair users may be dependent on another person to perform everyday activities. In this paper we are conducting qualitative research to assess the users’ acceptance and perception of a novel wheelchair system that helps users to dance and practice physical exercises with music. In this new system, the user watches a dance video on the PC and follows the teacher with his/her upper body and arms while the chair moves with the teacher’s lower body and hips. The user can be connected online with others to dance together in a social networking online for dancing. The system is described in a video prototype and 10 participants are interviewed to assess the idea from different psychological aspects. The 10 participants include wheelchair users, wheelchair dancers and wheelchair dance teachers. Five themes emerged from the data; automation vs. free control, movement factors, motivational factors, social factors and usability issues. We gained a better understanding to why the user may like or dislike each feature of the system. We concluded that we can have a better empirical view about the system from the user’s perspective which leads to both defining a better design considerations and a providing the first step towards developing a survey tool to better assess future work of a real system.
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INTRODUCTION

Wheelchair users may experience physical and psychological challenges due to the difficulty to move outside their houses specially in countries with less facilities provided for them. As a result, wheelchair users might become more dependent on others to perform their everyday activities and may become unable to join much social and physical activities outside their houses. Daily activity and physical training is important as well to avoid stiffness of muscles and further health complications. Wheelchair sports may help the user to avoid physical complications and join more social activities.

Wheelchair dancing is an influential sport that can help wheelchair users to experience movement in a new way. Wheelchair dancing is a mature sport in 20 countries and is mostly focused on Ballroom dancing and Latin dancing. It belongs globally to “The International Paralympics Committee” (IPC), which organizes world championships and other competitions. Wheelchair dancers may participate in Combi style dancing with an able-bodied (standing) partner or duo-dance for two wheelchair users together. There are also Formation dances for a group of dancers dancing in formation. There are a few dancing companies that practice other types of theatre dance on wheelchairs. Wheelchair dancing differs from other sports in that it accepts all levels of disability and can vary from simple body movements to complex and precise wheelchair control at the competition level.

Wheelchair dancing can have a host of positive psychological and physical effects. Kunstler et. al. (2010) studied the effect of dance on Parkinson’s disease patients. Patients joined a real dance class and reported that they have gained confidence in their balance and stability and were encouraged to move. They especially found joy in the sense of community with one participant saying: “The pleasure of the experience is that it is not a therapy session!” (Kunstler & Daly, 2010). In another study, a group of Parkinson’s patients who received 20 Tango classes had better balance than the control group who received 20 exercise classes. Learning Tango involved focusing on stretching, balance, footwork and timing while in the exercise class, patients sat on a chair or used a chair for support. The results show that we shouldn’t underestimate the capabilities and desires of patients to learn complex moves (Kunstler & Daly, 2010).

Little research is available that specifically focuses on wheelchair dancing. A qualitative study by (Goodwin, Krohn, & kuhnle, 2004) focused on the phenomenology of wheelchair dancing for five children (4 girls, 1 boy; ages 6-14 years) with Spina bifida (aka ‘split spine’ leading to leg weakness and paralysis). The children reported feeling a sense of belonging and pride in their
accomplishments. They came to perceive their wheelchairs as more than a means for transportation; the chairs had become part of their dance. They also reported that dance was their own form of freedom of movement. One participant reported that she discovered muscles that she didn’t know that she had. (Goodwin, Krohn, & Kuhnle, 2004).

**THE STARTING POINT OF THIS RESEARCH**

In our previous research we conducted an empirical study observing a number of wheelchair dance classes and competitions to gain an empirical insight and a rich picture of the wheelchair dance scene and to get closer to the real users to understand their experiences, perceptions, needs, abilities and limitations. The study used field observations, interviews and a survey as methodology. The goal of the study was to propose a better control mechanism for the wheelchair to help wheelchair dancers perform the dance more easily and expressively by controlling the chair with their upper body muscles instead of pushing the chair or holding the joystick. The idea was to give the dancers the possibility to express the dance with their arms while controlling the chair with their upper body. As the study was based on human centered design, the real users were involved in examining the idea from the early stages of the design (Kuniavsky, 2003).

The lived experiences of wheelchair users during the dance class completely restructured the perspective to wheelchair dancing that we had from watching online videos of wheelchair dance competitions. The study showed that wheelchair dancing is not mainly about impressing the audience with complex and artistic moves, but it is a social medium for wheelchair users to enjoy dancing, music and the social contact with other wheelchair users. Each dancer can move in his/her own way and based on his/her own abilities, regardless of the specific type of disability or the type of the wheelchair. Dancing induced happiness to dancers because their disabilities were not limiting them and the dance didn’t have restricting rules. The shape or aesthetics of the dance is not necessarily the primary source of enjoyment; rather the social and psychological factors are causing the greatest satisfaction to the dancers. These findings were consistent to the study by (Goodwin, Krohn, & Kuhnle, 2004) which mentioned the value of “unconditional acceptance” and the social aspect perceived by children. They experienced an “unconditional acceptance” by performing the dance in their own way without any limitations or conditions. The study emphasized the role of the social aspect in the dance class: “*The dancers danced for the love of being with other dancers, to feel happy, to remove daily stresses, and experience the joy of movements.*” (Goodwin, Krohn, & Kuhnle, 2004, p. 243).

Despite the value of wheelchair dancing, we uncovered in our previous research a number of challenges and motivational barriers (de-motivators) that wheelchair users face while dancing. These barriers may also impede others from joining the classes. The first challenge is upper body pain caused by moving the chair. Participants repeatedly mentioned pain in their shoulders and back, and many of them recorded having limitations in their upper body as well as their legs. The second challenge is the difficulty and cost of transportation to the dance class, in particular since there are only a limited number of classes, and they are not usually geographically close. Third, in most of the cases dancers are dependent on a healthy family member to support them to reach the class and to dance together. As a result, we identified the need for a technology that can overcome these
obstacles to help wheelchair users benefit from the physical, psychological and social values of dancing.

In the current research, we continue on our previous work by proposing a different setup for dancing that can make use of the benefits of wheelchair dancing while overcoming the previously discovered challenges. We call this new design the “Connected Dance Chair”.

**WHAT IS THE CONNECTED DANCE CHAIR?**

The Connected Dance Chair is a new concept of a wheelchair system that helps wheelchair users to practice physiotherapy and dancing at home on their own while connected to a social network of users who want to practice on music together. The user will be watching an instructor performing a dance on the PC. The user starts practicing with the instructor and music. The chair has sensors to understand the users’ upper body movements and hence starts moving to follow the user’s movements. The user can design his/her own dance by programming the chair according to a specific dance video. The user can connect online with the software to share the dance with other online dancers. A simple diagram of the dance chair is shown in the next figure.

Hence the Connected Dance Chair system has the following features:

**THE DANCER CAN STAY AT HOME**

As we discovered in previous study the challenge of physical transportation to the dance class, the Connected Dance Chair allows the user to dance and/or physically exercise at home without the need for difficult or expensive mobility solutions. The user can perform a training frequently without restriction to the time or location of dance classes. It is important to note that this is not a replacement for physically going to dance classes but rather offers an additional alternative to people who cannot reach a class or who are unavailable at the time the class is taught.

**THE DANCER IS WATCHING A RECORDED VIDEO OF A DANCE GROUP OR ONE INSTRUCTOR**

By watching an instructor performing a dance with a group, the user might be more motivated to follow the instructions than doing the exercise alone. Research by (Miller, Litva, & Gabbay, 2009)
explored the effect of using a video tape of physiotherapy exercises by 33 patients with shoulder and back pain. The research concluded that using innovations such as videotapes (or DVDs/Internet) can play a useful supporting role for the provision of physiotherapy, offering choice to patients and physiotherapists in how they deliver activities between consultations. This suggests the value of self conducted physical exercises at home and the influence of using an instruction video. Irwin and colleagues (2012) have recently demonstrated that exercising with a virtually present (i.e., online or videotaped) partner can improve performance on an aerobic exercise, where people in co-active conditions exercised longer than those in individual conditions. They attribute this effect to the Kohler Motivation Gain, which predicts a low-ability group member to work harder in a group where they appear to be the ‘weak link’ than if s/he were working alone (Irwin, Scorniaenchi, Kerr, & Feltz, 2012). Although our earlier research suggests that wheelchair dance classes are not necessarily very performance-oriented, social comparison effects are nevertheless likely to occur even in supportive contexts (Hodges, 2010), and may help improve one’s motivation to exercise.

**THE CONNECTED DANCE CHAIR CAN BE CONTROLLED BY UPPER BODY MUSCLES AND CAN MOVE ACCORDINGLY**

The chair will have sensors in its seat to understand the user’s body movements and posture. Based on these measurements and also based on a defined dance pattern, the chair will move in the direction and at the speed specified by the user’s movements. The level of automation of these movements versus user’s control over the chair can be adjusted and is a matter of further research. With this feature the system can overcome the problems of upper body pain by distributing the control load from the arms to different parts of the upper body muscles. The tradeoff between automated movement and the user’s control can be adjusted according to the user’s abilities and type and degree of disability for the highest physical benefit. This can also help the user to exercise or dance independently of others.

Controlling the wheelchair using upper body muscles is an old idea that is employed to serve users who cannot use their arms in controlling the chair (Min, Lee, Lim, & Kwon, 2002) (Pari, Rao, Junct, Kumar, Ostrowski, & Taylor, 2003). Intelligent wheelchair control became an interesting topic of research which explores different aspects of control. One direction is developing better means of control rather than the joystick, specially for users with cervical injuries (spinal cord injuries of the neck) who generally lack motor control of their upper bodies, shoulders, arms, and hands, and therefore cannot control a joystick. Another direction is concerned with developing better algorithms for mapping the joystick into movements. A third direction is involved in developing more intelligent mechanisms for involving the chair computer combined with the user actions to reach a better decision of movement. The concept of intuitive control, user friendly control, shared control were mentioned in many researches.

In line with our proposed solution, Min, Lee, Lim, & Kwon (2002) suggest a more human friendly wheelchair control that moves based on shoulder and head movements. The design is based on four human aspects guidelines; human friendly design, easiness of wearability, intuitive drive function, and low cost. Six high spinal cord injured participants tested the system. The system did not work properly with every participant however they reported satisfaction for being able to control the wheelchair without any assistance and with invisible wearable control.
The concept of shared or augmented control was discussed by Pari and colleagues (2003). They conducted usability studies for a shared control wheelchair system where the human operator selects the appropriate behaviour or goals while an augmented software is responsible for executing behaviours. The automated vehicle was able to react faster than the human response and therefore, avoids hitting the obstacle each time.

Another study by (Kuno, Nakanishi, Murashima, Shimada, & Shirai, 1999) explored a new design of wheelchair control by turning the face in the direction of the desired movement while the intelligent chair observes the user and outside environment to understand the user’s intentions from observing the face.

In these studies and other, similar ones, the goal of the control system is to provide an easier, more intuitive, more responsive and more intelligent control of the wheelchair for the purpose of mobility specially for users with limited motor abilities in their arms. However, to our knowledge, there is no control system that was specially developed for the purpose of dancing and interaction with music.

**The user can create his/her own dance design**

Another feature of the Connected Dance Chair is that the user can design his/her own dance by specifying the chair which movements in relation to specific parts of the dance, and related body posture. The user uploads a dance video and the system helps recognizing the tempo of the dance. The user then defines different types of figures where the chair moves in a certain direction and speed. The user then places figures inside certain moments in the dance to be consistent with music and the dance video displayed on screen. This feature can also be used by a physiotherapist to enhance specific motor or sensory abilities of the user and can be adjusted according to the user’s abilities.

**The user can share the dance with other users online**

As demonstrated by our own previous empirical research as well as other studies by (Goodwin, Krohn, & kuhnle, 2004), social context plays a major role inside the dance class. To enrich the system with the social factor, the user can share dance sessions with other dancers online, and users can enjoy real-time online social interaction. The user can ask another dancer online to dance together on the same video while seeing each other and gaining scores for their progress.

**Stages of this study**

This paper is an extension to our previous research as mentioned above. Both studies are based on a human-centered design where the user is involved in all stages of the design and the design is adaptive to the user’s needs, opinions and abilities. In this study we are not trying to convince the users with some idea or to sell them a specific product, but we try to share the actual users’ views about a conceptual design beforehand. Involving the user in all stages of the design gives a chance for an adaptive, open minded design that is based on a shared view between the designer and the user. Hence serving the users’ needs, experiences, limitations and abilities. This concept is known as user-centered design or “Iterative Spiral Design” which recursively examines the users’ needs,
defines a better approach and creates a practical solution (Kuniavsky, 2003). Following an iterative design approach increases the chance of practical success and usefulness of the design.

Our previous study inside wheelchair dance classes represented the first design iteration where the real environment of wheelchair dancing was examined and the users’ problems and perceptions were defined. A shared view with the actual wheelchair users about the concept of controlling the wheelchair with upper body muscles was examined. Based on the defined users’ experience, we proposed a new design.

The research reported for this Masters Thesis represents the second design iteration where the new proposed design is re-examined, based on a video prototype of the system, and the users’ opinions and views are shared again to redirect our design based on users’ experience. The result of this research would be an improved design that is subject to a new iteration in future work.

**REALIZATION OF THE CONNECTED DANCE CHAIR**

As the goal of this research is to explore the users’ perceptions about the new design concept, we need to show something to our participants. A real prototype was realized using a motorized wheelchair, a redesigned control unit, a body sensor network and tailored software. The chair was updated by adding a third motor to rotate the seat with respect to the base to add side movements. A new electronic control unit was designed and developed to control the three motors and to be connected to the computer. Three types of sensors (4 load cells in the seat, 2 distance sensors near the shoulders, accelerometers on the hips) were added to the chair and connected to the computer as well. Custom software was developed to control the chair in synchrony with a dance video displayed to the user. The full technical design documentation is covered in another document and is added as an Appendix to this report. A photo of the developed prototype and a snapshot of the software is shown in the next figure. More details about the software and the wheelchair can be found in the appendix.
RESEARCH QUESTIONS

Following up on our previous research, the central research question guiding the current study is:

**TO WHAT EXTENT CAN A DANCE AUTOMATED WHEELCHAIR HELP WHEELCHAIR USERS TO DANCE AND PRACTICE PHYSICAL EXERCISES?**

To answer this question from a human centered design perspective with a shared view between our design and the users’ experience, we need to answer a number of sub-questions:

- To what extent can features of the Connected Dance Chair *help* wheelchair users in overcoming the barriers identified earlier?
- How *attractive* are the 4 features from the user’s perspective and which one *is* the most attractive?
- Does the system add motivation to the users to *practice* physical exercises?
- What are the *limitations* and disadvantages of the system and why they are limiting.
- How can the design be *improved* to fit the user’s needs and abilities and how can the system features be tuned?
- What are the *usability* issues from the user perception like perceived safety and ease of use?
- What is the variance among users and what are the possible variables that may cause this variance?

To answer these questions, the following research methods were adopted.
METHODS

PARTICIPANTS

Ten participants were contacted through the wheelchair dance association in the Netherlands and through our personal connections with wheelchair dancers from previous research. Participants were visited at their homes where the interview took place. All the interviews were conducted in the Netherlands (in the cities of Eindhoven, Alkmaar, Amstelveen and Ede). Participants were chosen to have a relation with the wheelchair or wheelchair dancing in either one of the following roles:

- Wheelchair users who practice wheelchair dancing
- Wheelchair users who don’t know about wheelchair dancing
- Wheelchair dance instructors who are using a wheelchair
- Wheelchair dance instructors who are able bodied
- Able bodied dance partners who dance with a wheelchair users

As the goal of the research is exploring the general acceptance of users towards technology, the sample is not representative to the population. Each opinion is valuable for the research even if it is mentioned by only one participant. Future research may add more in-depth analysis of factors affecting opinions of users. Most participants were interviewed separately except 2 married couples who were interviewed together as a couple in a focus group style. The following table summarizes the information of the ten participants:

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VIDEO PROTOTYPE

Video prototyping is a technique for visualizing the interactive behavior of a system using video animation. In this study, video prototyping played an essential role in gathering user feedback. The video prototype explained the basic concept of the Connected Dance Chair to the participants. Although the video prototype was based on the physical prototype described earlier, a video prototype was used for two main reasons. First, the video prototype enabled a broader coverage of the full functionality of the system, including chair movement, a dance video, interaction with the software, synchronization and music. Second, the physical prototype was not yet deemed safe enough for use by this vulnerable group of users. In particular, the abrupt motions of the chair could not be entirely ruled out, and could provide a safety risk.

The video prototype was composed of a series of timed Powerpoint slides accompanied with narration describing the system functionalities and features. In between the slides a composite video was shown that demonstrated the physical prototype of the Connected Dance Chair in action. The video started with a summary of the Connected Dance Chair and its role in helping wheelchair users practice physical training with music from home without the need for difficult mobility solutions. A hypothetical user called “Marthe” was used throughout the whole video to represent the user of the system. The narrator describes that Marthe is a wheelchair user who receives weekly physiotherapy session and likes to watch wheelchair dance videos, but she cannot go to dance classes because they are far from her village and she does not have a partner available to drive her or to dance with.

The composite video was composed of 3 different videos mixed together in synchrony. The right part of the screen displays a dance video where a teacher is leading a group in a Zumba dance. This part is what the user of the dance chair will see on his/her computer. The upper left part of the screen shows an actor that plays the role of the dance chair user. She is seated on a normal rotating chair and is instructed to dance with the teacher’s upper body while rotating the chair with her legs when the teacher turns. The lower left portion of the screen shows a small model of a wheelchair with a small doll mounted on it to represent the supposed movements of the dance chair. The three videos are synchronized together. A screenshot of the composite video is shown in the next diagram.
The video was shown to the participant in stages played once for each feature. In between the four features, the participant was asked questions about each feature as described later in the interview guide. The participant was given a chance to express him/herself not only to answer the given questions but also to express any additional ideas and considerations that may come to mind. The interviewer stopped the video whenever the user wanted to state a comment.

The dance in the video prototype was chosen to have both slow and easy lower body movement and more complex arms movement to show clearly the idea behind the system. The video was developed in Microsoft PowerPoint, Adobe Flash and Audicity.

**Semi-Structured Interview**

A semi-structured interview was used to gather the users’ opinions, perceptions and experiences. As the goal of this research is sensitization (i.e., gaining an in-depth understanding of the subject) (Knafl & Howard, 1984), a semi-structured interview is used as a tool to allow the participants the opportunity to express their opinions openly in their own terms and experiences and to allow the researcher to engage in an in-depth discussion with the participant.

The interview guide is designed to focus on the four features separately and then asks general questions and compares them at the end of the interview. Participants were left to express their opinions freely outside the limits of the questions by asking them about their open opinions before asking specific questions. After showing them every feature, they were asked about their general opinions “What do you think about this part?”, before going to more specific questions like “Do you think it can motivate them to do that?”. 

Through the interview, the participant is left to express any thoughts that come to one’s mind. The interviewer explores these ideas whenever possible until the participant doesn’t have more to say.
Participants are encouraged to speak as much as they want. In this manner, the interview is a semi structured interview.

Participants were instructed to speak freely without trying to be nice to the interviewer about the system and they were informed that it was just a conceptual idea not a product that the interviewer was trying to sell. Participants received a short description of previous research conducted in wheelchair dance classes and its results and the goals of the current research.

Participants were asked permission for recording the interview. On average the interview took around one hour and a quarter. The interview took place in English. All participants were native Dutch so English was not their native language but they were fluent enough in English to express their thoughts. Afterwards participants received a small gift like chocolate or flowers.

The interview consisted of the following sequence of questions:

[The participant is shown the automated movement feature in video]

- What do you think about this idea?
- Is it motivating?
- Is it scary?
- Is it uncontrollable?
- Do you think it might give a feeling of free control or more limitation to the body?
- Can you think about it as physical exercise or dancing?

[The participant is shown the upper body control feature in video]

- Do you think it is useful in anyway?
- Do you think it can be motivating?
- Do you think it can be used to train muscles?
- Is it confusing?
- Does it feel safe?

[The participant is shown the dance designer feature in video]

- Is it useful in any way?
- Is it easy to use?
- Do you think it can be funny?

[The participant is shown the online dance feature in video]

- Do you think it can be motivating?
- Does it affect the social activity?
- Can it trigger making friends?
- What would you think of the system if we remove the motors from the system to make it cheaper?
• What is the most attractive or useful feature for you?

DATA COLLECTION

The interview was recorded using a high quality Olympus voice recorder and was transcribed immediately afterwards. No other data was collected.

ANALYSIS

Transcribed interviews were analyzed using a grounded theory approach. An open coding was used by identifying, naming, categorizing factors found in the interviews. Each new evolving factor was searched for in the entire data set until no new factors were identified. Each related group of factors were categorized under one theme. Any participant’s opinion was extracted even if it was mentioned once. Conflicting opinions were categorized under the same theme and analyzed in the discussion. (Knafl & Howard, 1984), (Ryan & Bernard, 2003), (Raftopoulos, 2005)

In the following sections we will analyze each factor separately supported with the participant’s quotes. These factors should not be considered as a conclusion or representation for the whole population, because these are only 10 participants and the population has a big variance in the types of disabilities, perceptions, experiences and needs. However, these factors are used as attention points to add more depth to understanding the human physical and psychological interaction with the chair. This is important to be considered in prototypes design and to create a detailed questionnaire for future research on a bigger population.
RESULTS

When comparing the ten interviews, we find clear variance in participants’ opinions and attitudes. In many aspects there were some similarities as well. This shows that the acceptance of this type of technology is very dependent on the user’s specific conditions and also some variables in the system. Factors like the type of disability, age, availability of external support and specific personality traits might be among the reasons that caused the variance in attitudes towards the technology. Participants’ attitudes varied from very realistic and practical to optimistic towards the benefits that may be gained from the system. The human factors that emerged from the ten interviews were gathered and categorized in themes. Five major themes emerged from the data:

**Theme 1: Control Factors: Automation versus Free Control**

In this theme we collect the participants’ opinions and experiences related to controlling the chair with their bodies and controlling the chair from an automated software program and the values and limitations of each scenario.

**Theme 2: The Body in Movement**

In this theme, we group participants’ comments related to the value of movement and the relation between the user’s body and the chair in movement.

**Theme 3: Motivation Factors**

In this theme we group participants’ ideas about possible enhanced motivation to practice physical exercises caused by music, video and movement.

**Theme 4: Online Social Connectedness**

In this theme we group participants’ perceptions about the social value from sharing a dance online with other users and other social aspects related to wheelchair users’ everyday life.

**Theme 5: User Acceptance and Usability**

In this theme, we explore usability issues that can make a useful technology unusable including ease of use and simplicity and also financial factors.
**Theme 1: Control Factors: Automation versus Free Control**

This theme contains all opinions that appeared related to the source of controlling the chair movements. The chair can be controlled either from software (automation) or based on the user’s upper body movements (free control) or a combination of both (shared control). The tradeoff between these sources of control was discussed by participants. Participants mentioned why each source of control can be useful or limiting.

**Factor 1.1: Dance Starts from the Mind**

Some participants mentioned the drawback of fully automated control because dancing is an activity that has to start from the person’s mind and perception of music and beat based on feeling and cannot start from a machine. Most of them preferred shared control as the user triggers the movement not the computer. They saw the user’s body and mind as a part of the control cycle without which the chair cannot move.

> “I think it will feel like in a roller coaster (fully automated control), it is fun but it is not like you are doing a dance, when you are dancing you are translating the music into moves. This is different than when the music is playing and it is connected to the wheelchair through a wire and you are on the wheelchair, it can be scary for some people I think.” (Participant 6)

> “It sounds better (shared control better than automated control) because you are not a doll, and you are doing something and because you are moving the chair is moving. You are active, in the first one you are not active” (Participant 4)

> “That is better because it is not starting from the engine but from myself. That is better, much better” (Participant 5)

**Factor 1.2: Anticipation of Body Movement is Essential**

Most of the participants mentioned the importance of anticipation of the next movement by the user because otherwise it will be shocking and unpredictable. Participants preferred that the user would practice the moves in advance and has time to get prepared for the next movement because wheelchair users are already handicapped and cannot correct their body position as fast as able bodied users.

> “They have to learn the choreography then they do it together or step by step because otherwise the chair is moving and they get confused because it is on the same time ” (Participant1)

> “The only thing I am afraid that the person gets surprises so they must first know where the chair is moving, they must know how, if you don’t know, it is not good for the body ” (Participant3)
Regardless of the user’s ability to move the chair, participants repeatedly mentioned that users with spasticity get scared and shocked from sudden movements and sounds. Therefore, an automated control may be scary for them and also may cause more stiffness in their responses if the automated movements are fast, sudden or unexpected. On the other hand, spinal cord injury users and users with amputations might be more in control.

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**Factor 1.3: Balance is not easy with wheelchair users**

For many wheelchair users the body balance is an important aspect that is not as easy as in able-bodied users depending on the type and location of disability. As a result, the arms need to be dedicated for keeping balance and the moves need to be slow and predictable. Prior knowledge of the movements is essential for balance and sense of safety. Depending on the type and location of the disability, users may have difficulty balancing themselves. Users with high spinal cord injury may have the biggest difficulty in balance because they only use their arms to maintain their balance as muscles in their backs and/or abdomen are disabled while users with amputation or low spinal cord injury can still use their abdomen and back muscles to maintain balance.

“I think it will be very difficult, for me it is very difficult to move my arms and at the same time stabilize while the chair is moving because I need my arms and hands to stabilize myself, if the chair is moving I have to correct my upper body to keep on the chair otherwise I will fall.” (Participant 6)

“One disadvantage I see is that people in the wheelchair often have difficulty moving and balancing so either the wheelchair movements has to be really slow so the person can adjust or the movement has to be connected in some way to the movement of the person” (participant 6)

Participant 7 emphasizes this fact as she is specialized in human kinetics and she suggests using the system to practice balance in the same way.
“I think it is a bit like Wii balance board, I think you can also make balance exercises on this because many people on wheelchair also have difficulties with their balancing, so I think it is a good training because when you reach you have to balance again because you have to come back to the vertical position” (Participant 7)

**FACTOR 1.4: CONFLICT AND CONFUSION MAY CAUSE MORE RESTRICTION**

This Factor is clear when the user tries to move in a different direction than the intended movement, so the chair will not move or will move in a wrong direction. If the chair is moving in some direction and the user wants to move in another direction or moves in other direction by mistake, then one will feel more limited rather than free. Participants suggest that the chair follows the user movement regardless of whether they are following the music or not.

“I am not sure it is good that it takes its moves from the TV because if the person is doing different moves... it can go wrong, the chair has its mind on its own” (participant 9)

“Such a moving chair with a system should be very close to you otherwise, it won’t be any help. Exactly moving the movement with the same type of music will feel like the chair will hit you” (Participant 10)

**FACTOR 1.5: SHARED CONTROL MAY LOOK LIKE A REWARD RATHER THAN FUN**

The shared control feature is introduced as the chair will only move with music if the user moves in the correct direction. Participant 6 perceived this scenario as a reward rather than fun and it might also cause confusion to the user if the chair doesn’t move. Participants suggested that the chair has to move freely with the user body and the system should only feedback the user with the correctness of the movement while keeping the chair following the user’s movements to maintain a feeling of free control.

“In this part the movement of the chair seems like some kind of reward to moving the right muscles. But the way I look at it is that I am dancing and I am telling the chair what to do not the chair telling me what to do” (Participant 6)

“But the way I think about it is different, the control starts from the person and the wheelchair follows him and sends these movements to the computer, if the person is doing something wrong, the PC tells him that he is doing a mistake and in that way you have a circle of person to chair to video to person” (Participant 6)
**FACTOR 1.6: USERS WITH LOWER ABILITIES MIGHT BENEFIT FROM A HIGHLY AUTOMATED CONTROL**

Interestingly, participants 2 and 3 who are experienced wheelchair dance teachers saw that there is a significant number of users who have handicap in their upper body muscles and rely on a partner to move their chair from behind. They saw the automated movement as a big benefit for these types of users and the controlled movement as a limitation for them. This opinion does not contradict with other participants because they are speaking about different types of users. For one type it is a limitation and for the other it is an enhancement.

“As you have seen in the competition, there are people in the wheelchair and there are other people who push them from behind because they cannot push their chairs; but they dance because the feeling in the body is the same and that’s what you do without help so they can do it on their own and that’s very important” (participant 3)

“A big problem for a lot of people that they don’t have the strength to move the chair strong enough to dance with it so if some type of technology enhances their movement and makes it easy for them, it will be a big advantage, definitely” (participant 6)

“It depends on the person, there are persons who totally can’t move, for them it is better when the chair moves, and they can enjoy the movement with the music, but there are people who have one leg and complete healthy upper body so they can move their arms and they don’t need a chair that moves by itself” (Participant 2)

In addition, some participants saw that an automated system may also reduce the dependency of wheelchair users on others.

“We gave lessons in Goirle and to give lessons to 5 people we need other 5 standing behind the chair and they are not available so we had to switch, but with this chair we don’t need these people” (Participant 2)

“For people in wheelchair, it is very important that they can do something without help because in their whole life they need help with going to bed, washing, stand up and if they can do dance without help, it can be a miracle for them” (Participant 3)

“I think if you are so heavy handicapped that you can’t control it yourself then you will be very happy with that because otherwise you can’t dance and you always need help” (Participant 3)

Upper body abilities are sometimes limited, therefore an adjusted shared control is necessary to follow the user’s abilities.
“In my opinion to do this dance they (users) must have fine motoric movements, otherwise the chair will move in all directions, so you have to know what they can do” (Participant 4)

**Factor 1.7: Personality preferences affect the acceptance of automation versus free control**

Whether people felt they would prefer transferring control to an automated chair or in stead remaining in full control themselves also showed to be a personal preference. As an example, Participant 8 has a chair without handles in its back and he mentioned that he removed them because he doesn’t want someone to push him. He repeatedly mentioned that he is very independent and does not want to be helped.

“For some people it is a very good idea but not for me. I want to move my chair myself because I want to be independent. I don’t want to be pushed. Spinal cord injuries are special type because we want to do everything ourselves” (Participant 8)

**Summary**

The first impression that appeared on the participants when they watched the automated motion of the chair with music without the user control (Feature1) is the lack of free and conscious user control of the system. In most of the cases, participants saw that as a drawback of the system. Each participant mentioned one or more interesting concept why this is considered a limitation or advantage. As a result most participants saw that shared control is better than automated control. Interestingly, some participants considered automation as a benefit for users who cannot control their chair and have to rely on a partner and they mentioned that there are users who always need someone to move their chairs from behind.

**Theme 2: The body in movement**

In this theme we group opinions related to movement including the physical value of movement, how can movement be implemented in the system, how can movement be enjoyed by users, the role of movement in the dance chair system compared to other features.

**Factor 2.1: Physical challenges and the value of exercise**

Participants in general mentioned the lack of physical exercises for wheelchair users. They also mentioned isolation problems and difficulty of mobility. Participants agreed on the benefit of any simple physical movement because wheelchair users normally don’t practice much exercises.
“A lot of wheelchair users sit at home waiting for something to happen. But do not stay physically active themselves so they don’t go to Aerobics class because there is no one for wheelchair users but they have to move more” (Participant 7)

“There are too many people sitting in the wheelchair and they don’t do anything because they think they can’t do anything and this can be a possibility to get out of their isolation, I only hope it will be affordable” (Participant 7)

“They don’t socialize with the whole community, they stay behind it. Some people totally not and some a little bit … Now in their mind they feel when they dance for an hour or two, they feel nicer in their body and more fun in their life” (Participant 3)

**FACTOR 2.2: SIMPLE MOVEMENTS ARE MUCH APPRECIATED**

Participants emphasized that simple movements on the wheelchair that do not look attractive for us might be very attractive for wheelchair users because they compare it to what they can already do on the wheelchair. Participants’ view to movement is a comparison between a limited situation to a less limited situation or an upgrade from doing nothing to doing something:

“But if you can’t move and you have a chair which can move on its own you will be very happy because they normally stay at home” (Participant 2)

“If you are handicapped you can’t move and if you get the possibility to move on your own way a little bit, then it is wonderful for them” (Participant 3)

“So it would be better to have a machine that can help in that, better than sitting in a chair without doing anything” (Participant 9)

**FACTOR 2.3: STIMULATING MUSCLES AND BODY AWARENESS**

Participants mentioned that exercises activate muscles and may help the user know which muscle is still working. They saw users who thought they cannot do some moves and were not aware of their body abilities and could develop later difficult movements from dancing.

“If they have for example an accident and they don’t know exactly what functionality is left and what they can use, this program can help them to know, this muscle is working, oh this muscle is still working” (Participant 1)

Participant 7 who has studied human kinetics, also mentioned the possibility to stimulate the brain by moving the chair in certain directions followed by certain body movements. In her opinion, the
dance chair can be a tool in the hands of the physiotherapist to stimulate muscles that he/she is interested to stimulate:

“If you cannot move one half of your body you can tell the program that when you move your right arm it turns the chair to the left which can stimulate your brain to do a bit more with the other half too! Because they feel that one half does not exist so you have to stimulate that that side is there” (Participant 7)

FACTOR 2.4: BODY EXTENSION

In the interviews participants mentioned the expression “Body Extension” frequently when speaking about a good wheelchair. They showed to be aware of this difficult expression from their daily experience with the wheelchair. They mentioned that a well fitting wheelchair will move when the user moves without using his/her arms otherwise it will be restricting to the user.

“The most important thing if you have a wheelchair that fits like shoes on your body then when you go naturally your wheelchair goes already with you in the direction that you want” (Participant 10)

“A normal wheelchair also moves when you are sitting in it and it fits right, when you are moving like that it also moves, so if it is not moving it will hold you back, so I think it is good that it moves a little bit and it is a bit more extension to your body when it moves a little bit” (Participant 7)

Participant 6 who is an active sportsman, perceived the concept of body extension in wheelchair tennis. He attributed the concept of body extension to the user’s abilities to control the chair and not only to the fitness of the chair:

“But if you are good at wheelchair tennis both will become one so you will use one arm to adjust the wheelchair and the other to hit the ball I think it is the same for dancing” (Participant 6)

“In the beginning it will be confusing but if you make the chair “een Verlenging van het lichaam” (an extension of the body), if you make the chair an instrument that can be controlled by the person in it, they will learn and at the beginning it will be very hard but they will learn, it is like driving a car” (Participant 6)

Participants repeatedly mentioned that certain sitting positions may help to move the chair more easily in corresponding directions. They explained that the involvement of the upper body in the control of the chair is a known technique in movement and dancing.
“In wheelchair dance it is easier to turn when you are leaning to a certain direction so if you make it move when the user starts motion in some way then it will be an extension to their body” (Participant 7)

**FACTOR 2.5: FREEDOM AND EXPRESSION**

One of the goals of the system is to give users the chance to move their arms freely to express the dance while the chair is moving to follow the body. Fewer participants noticed this point while the majority of participants were more attracted to other points. Participants who mentioned freedom of arms from controlling the chair, were sensitive to the value of arms’ movements in perceiving the dance and experiencing more abilities.

“If they only move the chair they miss the happiness with moving their arms, but I am sure from experience that wheelchair users would like to move their arms with standing partners. If they don’t move their arms they get a little bit de-motivated and bored because they have nothing to do” (Participant 1)

“People in electric wheelchair, they are so busy to have a control of the joystick that all the other energy gets lost and if they have nothing to do with the joystick they have other possibility they are free to do” (Participant 1)

“I think the feeling can be great because most of them were able bodied before they use the wheelchair and they can experience again the feeling that they are dancing without holding it but only for the time that the chair is connected to the PC” (Participant 5)

**FACTOR 2.6: THE VALUE OF MOVEMENT IN THE SYSTEM: WHAT IF WE REMOVE THE MOTORS AND ONLY KEEP THE SENSORS AND SOCIAL ASPECT?**

To keep the system simple, feasible and affordable, participants were asked about the value of the system if the movement factor is removed while keeping the sensory option and the social aspects of online sharing. Some participants saw that this would be more feasible, affordable and a simpler step and they saw perceived movements as not the most important feature of the chair.

“It will be more affordable” (Participant 5)

“The chair does not really have to move because you have to watch the screen also and for some people can have problems in vision to move and watch the screen at the same time” (Participant 7)

While other participant saw that the system will lose its value when the motor reaction is removed.
“I think it loses its fun, because the fun thing is the movement, the thing that makes people enjoy it is the movement and that they will feel they can do more with the right technology. But if it is just the computer telling you right or wrong it is just like solving an equation, it takes the fun out of it” (Participant 6)

“Perhaps you could take the example of the play station game that you dance on a matt and it just gives you score, but with the new xbox the camera can show you people really dancing and I think sensors alone with scores is less fun that when there is interaction and movement with it” (Participant 9)

Others saw that it depends on the user’s abilities and that movement may even be a challenge rather than fun in some cases like in case of users with spasticity who might perceive movements as scary.

“It also depends on how it can move and on the level of disability, for spastic person it will be easier if it doesn’t turn but for someone with a low lesion, it will be motivating when it does turn and move so they feel they are doing something. So it is hard to say for the whole population” (Participant 7)

SUMMARY

In this theme, we can see that participants’ attitude towards the movement of the chair is contradicting. Some of them valued the movement as it gives fun and stimulates the muscles and provides more abilities to the users while others saw it as not the most important feature. In all cases, participants mentioned that it is important to keep a connection between the chair and the user’s body. They stressed that a key factor in a good chair is its natural and intuitive extension to the human body. They mentioned that body extension is an old consideration and that changing the body posture while moving and dancing is a well known mechanism to facilitate movements in different directions.

THEME 3: MOTIVATION FACTORS

Motivation is defined as a process that elicits, controls, and sustains certain behaviors. The main goal of the dance chair system is to motivate wheelchair users to practice physical exercises more frequently. This is intended to be achieved through the four features of the system as explained in the introduction; automated control, shared control, choreography designer and online social sharing of the dance. In the interview, participants were asked if each feature can help users to become more motivated to practice physical training through the dance chair system and why. In this theme, we group the differing views of participants about the possible role of the dance chair to
enhance motivation. The concept of motivation was familiar to participants and they saw that it is a big challenge for physiotherapists:

“People who come to rehab center they are shocked when their lives change from one day to another day so it is very hard job for the physical therapist or the occupational therapist to find out what they can do and how they can motivate them, and if there is a sensor in the wheelchair and only when they try to move it the chair gets moving, they will do it. Because if they don’t think to move, the sensor will not work” (Participant 1)

**FACTOR 3.1: MUSIC AND VIDEO ATTRACT ATTENTION OVER DE-MOTIVATORS IN PHYSIOTHERAPY**

Participants saw the value of music in creating a cheerful environment that is less boring than a physiotherapy session. Participants also mentioned that an example video is influential because it provides an example to follow. Participants saw that music and video can motivate the user to move.

“I think they will feel they are more taking part in the program not that the physiotherapist is saying you have to do this and this and this and this... and stretch and bow and stretch and bow and you have to do it 10 times. They get boring of these exercises but you give them the feeling of dance” (Participant 1)

“Normally they go to a physiotherapist, and he says move your hand up and down .... And with music they can move it 20 times without feeling, and their mind is only busy with music and their hands are moved automatically. But with the physiotherapy they say I can’t move and it is hard for me” (Participant 3)

“I think it is better than therapy because in therapy there is no music, so people get bored but here you can make a big party of it, I think it is a good idea when you are at home and a little bit down and you have example on the screen so you can do it also” (Participant 5)

**FACTOR 3.2: MOVEMENT MAY ADD MORE ABILITY, FUN AND HENCE MOTIVATION**

Other participants focused on the value of movement and mentioned that movement on its own is a source of entertainment, fun and motivation because movement facilitates the exercise:
“I think in a different way (contradicting with her partner), when I am alone and I am a little bit down and want to do something but don’t know what, I will put the program and have fun and move, without this program I don’t have an example but when I am dancing with my arms and the chair is moving it feels better” (Participant 5)

Participants appreciated the value of movement more than other features because it gives the user more abilities and possibilities than one could without this technology. They mentioned that without movement, it would be more difficult and restricting to the user to follow a dance video.

“I think it will be a lot more motivating (adding movements to the chair); because if you are watching a video and trying to do what these people are doing there will always be a problem because you will not be able to do it yourself. The persons are walking on their legs and you can never be like these people” (Participant 6)

“It is more interesting for users to follow something in the screen because otherwise you are still, so I think it will stimulate people to do it because when you are sitting at home and you have a video and you just move like this, you will get bored after few times, so I think it is a good thing to add something to stimulate to do it again” (Participant 7)

**FACTOR 3.3: LEARNING AND PROGRESS CAN ACT AS A BIG MOTIVATOR**

Participant 6 who is a sports fan, compared wheelchair dancing to other sports. He saw that the learning progress is a source of motivation regardless of the end result.

“I think it is not about doing the movement exactly like the teacher but the system can just tell you if you do it correctly then you can take 20 points... this will motivate to do the movements better the next time” (Participant 6)

“It is not about destination but the journey and the learning factor is the psychological aspect of sports and dancing” (Participant 6)

Participant 6 mentioned that it is important to let the chair move in a wrong direction and give the user feedback about one’s mistakes to give a chance for learning and progress based on feedback from the system rather than not moving at all if the user does not move correctly:
“If the chair stops you think what am I doing wrong and you get frustrated. You want to move and dance and do things... it is like tennis, if the cannon does not send you the ball if you are not holding the racket in the right way then you can never learn, but you have to hit the ball and you have to practice the movement million times until you do it right. The feedback has to go to the person otherwise there is no learning loop” (Participant 6)

**FACTOR 3.4: MOTIVATION MIGHT COME FROM DOING AND CREATING SOMETHING**

Despite the feature of creating a dance design was perceived as difficult and complex, some participants mentioned it as a motivation by being part of the program through creativity.

“They will get creative and not only wait what do I have to do but think what I can do” (Participant 1)

“Dancers are only following the books and maybe you can do spectacular things where you can better perform” (Participant 8)

“I think it (body control) really can motivate people because you can actually see what you are doing because when you move it yourself it is a bit like an exercise because you really have to move your chair on your own” (Participant 7)

**FACTOR 3.5: MOTIVATION COMES FROM INSIDE THE PERSON**

On the other hand some participants claimed that a big part of motivation must come from inside the person and therefore the dance chair might not be that helpful. They claimed that people who are self motivated will always find something to do and others who are not motivated will not try the chair. They attributed motivation completely to the person:

“But you have to want it also, if you are not motivated I doubt it will help, and people who are motivated they do a lot on their own” (Participant 4)

“It depends on the person, I have always been social and active (before using the wheelchair) and I am still but for others it is more difficult” (Participant 6)

Participant 6 also mentioned that the motivation has to be intrinsic and the learning experience may enhance this intrinsic motivation.
“The person has to produce his own motivation. And the only way to do that is to let the person experience what they can do. Not tell them if it is right or wrong but you tell them we think that this is what you can do and try doing it” (Participant 6)

Participant 10 claimed that people go to the dance class are mainly for the social aspect, and therefore if the system is only based on the physical aspect they will not do it unless the user is really motivated on his/her own to practice exercises.

“You see in the class that most of them most of the time they sit on the side and talk and have a drink more than dancing. If you do it at home then you have to be motivated yourself” (Participant 10)

**FACTOR 3.6: TECHNOLOGY MIGHT ADD MORE DE-MOTIVATORS**

On the other hand participant 10 mentioned that a heavy or complex technology might cause frustration and might de-motivate the users if it is very complex or if it doesn’t fit them in a comfortable way. She mentioned that technology must add something extra to their everyday lives in the easiest and simplest way. This aspect will be explained more in the usability theme.

“It has to contribute something extra otherwise if it is too complex, if it takes too much effort or too much tuning then people don’t do it anymore. Because we have to do so many things to keep our body in a good condition, and if it is an extra then it won’t work, it has to go easy and contribute.” (Participant 10)

**SUMMARY**

Participants were divided into two groups; some mentioned different reasons where the dance chair can give extrinsic motivation to users to practice more exercises while another group saw that motivation has to start from inside the person (intrinsic motivation). In their opinions, motivation may come from music, movement, the learning curve and creativity. While others saw that dancers mainly enjoy the social aspect and at home they must find their own motivation. Some participants mentioned that the feeling of achievement and progress is an influential source of motivation.

**THEME 4: ONLINE SOCIAL CONNECTEDNESS**

In this theme, we group users’ opinions on the online dancing feature of the system and explore how it is attractive to them and how they perceive it as motivating for the users and why.

Participants repeatedly mentioned the social challenges that face wheelchair users. They mentioned the need for an able bodied partner and the need for support to move outside their homes.
“We have so many wheelchair users who want to participate but we don’t have enough partners so we create a single dance because we think come to our class and if you have no partner just come to our class then we get them in. sometimes they create a new couple themselves” (Participant 1)

“For a lot of people it is hard to go outside so it (online dancing) will make them feel like connected and may be they can even make new friends doing this dance” (Participant 6)

**Factor 4.1: Sharing the dance online can be a big benefit**

One of the few factors that all participants agreed upon is the value of the online social dance. They agreed that this can be a big social benefit for wheelchair users.

“You can go in one room and make fun with other people like skype, dat is leuk” (Participant 5)

“People are becoming more and more social on the internet and it is a way of connecting without the difficulty of moving” (Participant 6)

“There are a lot of wheelchair users isolated so if you can add something to do it by 2 players then you have competition and then you don’t need an able bodied partner, then it is easier to have a partner and also people who live in homes” (Participant 7)

“When you make an appointment with someone to go dancing you will do it” (Participant 7)

“This is a good idea, for sure, it is like what I am doing with other ones with scruble on the ipad, I do it with other players. You can chat in the mean time, so you have contact and youngsters are many open to all these kinds of interaction” (Participant 10)

**Factor 4.2: Sharing with able bodied users can be an option**

Other participants mentioned that the dancing network can be shared normally with other able bodied dancers where the wheelchair user will not feel as an intruder.

“It can be extended to compete with able bodied users as well like programs with Wii and xBox, so it can be connected to USB and compete with your friends like the Wii balance board but for the wheelchair. Then you won’t be the outsider and it is a small step” (Participant 7)
"I think you should compare it with internet dating and this dancing thing is the next level it is not just telling some person you are really beautiful and have blue eyes and I want to go out for a drink but you are dancing and enjoying and playing and having fun, even for people not having difficulty in moving, I think a dance web could be something" (Participant 6)

**FACTOR 4.3: ONLINE DANCING CAN BE A STARTING POINT**

Some participants mentioned that online social dancing can be an ice breaker towards feeling safe to join real dance classes.

"But to do exercises at home it is good because then you are already warmed up to go to the class and our class is only once a week" (Participant 1)

"I think they will try it first with someone they know just like hyves, I think it is easier to do it than they have to go to a dance class" (Participant 7)

"It is not like a real class but it is easier to start with because when you start with a class you need transportation and most people need someone to bring them because they are too isolated to go by themselves but when they know someone already from school or a rehab center, the step will be easier than going to a class where they don’t know anyone" (Participant 7)

**FACTOR 4.4: COMPETITION AND GAMING ARE MOTIVATING**

Participants agreed that the competition and gaming factors are an effective source of motivation.

"The social context can help because when I meet other people and you do it then I also want to do it" (Participant 1)

"I think yes because there is a competition element, more exciting, more a game now" (Participant 5)

**FACTOR 4.5: BELONGING TO WHEELCHAIR SOCIETIES OR TO THE WHOLE SOCIETY**

Participant 9 interestingly mentioned that many wheelchair users might not feel belonging to the wheelchair societies, but rather go outside with their neighbors and able bodied friends. This will make it more realistic to share the dance as a game with able bodied users and not being restricted to the wheelchair users.
“It has more to do with our society in a social view. When I was younger I went to a special school with everyone had a handicap, nowadays the government doesn’t separate people with handicap and the outcome that we don’t know each other anymore, and perhaps it is therefore harder to find other people in handicap to do sports together and we have the same problem in hockey” (Participant 9)

“Let’s say that there is a 16 year old girl that goes to a normal school and she heard about this chair, she will think well this is for handicapped and I don’t feel handicapped and I don’t know handicapped people, so it is nothing for me” (Participant 9)

“I think younger wheelchair generations who went to normal schools just go out with other neighbors or friends, they don’t search for other handicapped to go out with, it is not something you miss, so I think the younger generations will share it with their girlfriend who is not on a chair and they will dance on a chair and she standing” (Participant 9)

**SUMMARY**

Perhaps the social factor is the most salient among the benefits of the system and the main aspect on which all participants agreed to be useful and attractive. Participants were excited to comment on this feature and started to discuss different aspects of online social dance network and suggested different ways of making an online dance class. Participants supported their admiration to this feature by mentioning the social challenges that face wheelchair users. Some participants suggested to share the dance with able bodied dancers and others suggested that an online social dance may be compared to online dating.

**THEME 5: USER ACCEPTANCE**

In previous themes we discussed the advantages and disadvantages of the dance chair. In this theme we discuss factors that may affect the user’s acceptance to this technology regardless of its usefulness. In other words, what may prevent a user that believes in the usefulness of the dance chair to use it? Most of these factors may belong to the definition of usability, which is: “The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use”. While the last factor (cost and financial factors) may be viewed as a user acceptance factor.

**FACTOR 5.1: EASE OF USING THE DANCE DESIGN SOFTWARE**

All participants agreed that the dance designer software is very difficult and complex and may only be used by teachers who design a choreography. Others mentioned that young dancers can use the computer easily and are anxious to explore and play with new software.
“For me it is difficult for him it is easy but I am not a computer freak but the younger ones can do everything with a computer” (Participant 3)

“It is difficult, It is good for the teacher but not our dancers they are not doing this themselves” (Participant 4)

“I think it is too difficult, too complex” (Participant 5)

“I think it is not easy and a lot of users will not do it but the people who can, will post it on the internet” (Participant 6)

Regardless of the ease of use, some participants were more attracted to the idea of creating your own dance and they didn’t think much about the ease of use. They perceived the idea as useful for physiotherapy and creativity.

“Yes they will do it and they will get creative and not only wait what do I have to do but think what they can do. Sometimes I ask them to make something nice so to get them creative but most of the time the instructor makes it” (Participant 1)

“This will make it very useful for rehabilitation” (Participant 6)

“I think the one that you design your own dance because for physiotherapists it will be nice that you can add some movements in it that you want your patients to do in a fun way if they know how to use it. Maybe for wheelchair users it is more difficult” (Participant 9)

**Factor 5.2: Simplicity of the Apparatus**

Participant 10 repeatedly mentioned that many technologies are thrown in the cupboard because they are difficult to use or heavy or look bad. She was aware of how new technologies may be more restricting than helpful. This factor was a focus point mentioned by participant 10 more than other participants. Ease of use in her view was a group of factors including simplicity of the design, fitness of the chair to the body, ease of learning, ease of tuning the chair for each user, acceptance of the look and feel of the chair, time needed to use the chair versus its benefit of use:

“If things give you more freedom you will continue, or if it’s something else and I would do that too then it won’t help you” (Participant 10)

“It has to fit like a shoes, for example students with muscle diseases received a robot arm to help them in everyday activities and many of them refused it because they don’t want to be with a very big awful visible technology despite it was helpful” (Participant 10)
“the simpler the better, because the less I need to put on my wheelchair before I start the earlier I do it and the more energy it costs me I will not do it anymore” (Participant 10)

**FACTOR 5.3: MOVEMENT SPEED AND STYLE**

Most participants perceived the speed of the chair in the video prototype as very fast, confusing, may be impossible and will affect their sense of safety.

“If you make it slower it can be useful for people in electric wheelchair, but this is very fast. Then there will be bigger spectrum of people who can use it” (Participant 4)

“People in wheelchair often have difficulty moving and balancing so the wheelchair movements has to be really slow so the person can adjust” (Participant 6 about automated movement)

**FACTOR 5.4: EYE DISTRACTION FROM WATCHING THE SCREEN WHILE THE CHAIR IS MOVING**

Participant 7 interestingly mentioned that a moving chair while the user is watching the screen might be very distracting because not every user can easily focus on the screen while the chair is moving. She preferred removing the movement from the system to avoid this problem. Only participant 7 mentioned this point.

“The chair does not really have to move because you have to watch the screen also and for some people can have problems in vision to move and watch the screen at the same time” (Participant 7)

**FACTOR 5.5: COSTS AND FINANCIAL FACTORS**

All participants agreed that the cost of such a technology may be a big barrier to practically using it. As a result many of them preferred to remove the movement feature to keep it more affordable and a smaller and more practical step towards realization. Participants also mentioned the difficulty of getting or changing a wheelchair despite they mentioned that the Dutch government provides very good care for wheelchair users.

“Engineers may think in their minds to help people but then the community and all the society they have to think also in that way and they only think of money” (participant 1)
“I don’t know who will buy it because it is not needed for everyday life” (Participant 2)

“I think it will be very expensive then and this is the main problem. You can have a normal wheelchair every 4, 5 years but I don’t think that any office can pay for that wheelchair” (Participant 4)

**SUMMARY**

In this theme participants moved attention from the usefulness of the system to details that can make a useful system not practical or not acceptable by the users. Ease of use and simplicity were perceived as major factors for some participants. The most salient factor was the price of the chair which was mentioned by all users. Other factors were mentioned by few participants each. Except for Ease of using the dance software, other factors were mentioned by participants without asking them a specific question.
In this research we could successfully reach our goal of exploring the participants' minds, experiences, first impressions and opinions about the conceptual idea of the dance chair from different aspects. The result was not a quantitative conclusion about the acceptance of this technology, but it was an answer of the “Why” question in both directions of acceptance and rejection. Why each participant accepts/rejects, likes/dislikes, or in between opinion about every specific aspect or feature of the system.

**Motivation**

Not all participants agreed that motivation can be enhanced by technology and some claimed that motivation is intrinsic. However, all of them agreed that the online social dance can help to a certain extent. Deci (1975) divided the motivations underlying individual’s behaviour into extrinsic motivation and intrinsic motivation. Extrinsic motivation refers to committing an action because of its perceived helpfulness in achieving value, while intrinsic motivation refers to committing an action because of interest in the action itself, rather than external reinforcement (Davis, Bagozzi, & Warshaw, 1992). Davis and colleagues (1992) found that both extrinsic (usefulness) and intrinsic (enjoyment) factors affect the motivation to use information technology systems. These two motivations affect the individual’s intention to use information technology. Therefore, we can predict that participants' opinions about motivations (intrinsic and extrinsic) are valid in the context of the dance chair. Therefore the role of the dance chair is to improve both intrinsic and extrinsic motivations; i.e. enjoyment and usefulness. Participant 6 mentioned intrinsic motivation without a clear definition but he mentioned that improving this intrinsic motivation comes from the feeling of improvement and progress, perhaps this is the enjoyment part. Participant 10 mentioned that intrinsic motivation is when people practice on their own without social context. Perhaps she means that the social context induces enjoyment and practicing on its own is useful but not joyful. In general, the dance chair needs to fulfil both enjoyment and usefulness to enhance both intrinsic and extrinsic motivation. Enjoyment comes from music and the social aspect while usefulness comes from movement.

**Online Social Dance**

It was clear that the online social dance class is the most accepted feature by all participants. Participants perceived it as a motivator because of the competition and social factor involved. The online social dance may be considered as a web based interactive learning. The enhanced motivation to participate in an online interactive learning class was studied in previous research. Hernandez and collegues (2011) attempt to identify social motivations that underlie learners’ attitudes and usage behavior of ICT interactive tools. They proposed a comprehensive conceptual framework that identifies two groups of social motivations: anticipated reciprocal relationships and anticipated extrinsic rewards. The study empirically tested the framework in a university setting and revealed that both types of social motivations significantly influenced learners’ attitudes (Hernandez, Teresa Montaner, Sese, & Urquizu, 2011). The following diagram represents their conceptual model for social motivations of ICT interactive tools in e-learning. Based on this model, we can explain the value of an online dance class in socially motivating wheelchair users to join the
The model explains the socially enhanced motivation through social factors like sense of community, social influence, recognition by peers and instructor. These factors can influence the success of Web-based dance class and hence there is a need for future research focusing on improving the social aspect of the dance chair to optimize the socially enhanced motivation. These findings were also emphasized by Lin and colleagues (2011) who studied the factors that keep people use social networking sites. These factors included enjoyment, number of peers and usefulness (Lin & Lu, 2011). Number of peers may represent the social influence and therefore we expect that social norms are a factor in the users’ acceptance in technology as will be discussed later.

CONTROLLING THE CHAIR WITH UPPER BODY MUSCLES

Regarding the feature of controlling the chair with the users’ upper body muscles, participants were controversial about it. This feature was difficult to assess because it is highly dependent on the specific settings of the chair and the actual experience. However, participants admired this feature as it stimulates muscles (2.3) and because it enhances the sense of achievement (3.4) and the learning progress may enhance motivation (3.3). Previous researches used this concept for the goal of mobility (Kuno, Nakanishi, Murashima, Shimada, & Shirai, 1999) (Min, Lee, Lim, & Kwon, 2002). However, to our knowledge, the psychological impact of controlling a wheelchair using upper body muscles for the goal of dancing was not previously studied. We can predict from participants’ responses their conditional acceptance to the idea in case it can be intuitive, comfortable, easy to use and enjoyable. Testing a real prototype of a dance chair is essential to assess this feature of the dance chair.

MODELS FOR EVALUATING ACCEPTANCE, USEFULNESS, USABILITY OF TECHNOLOGIES

The research started with the question:

To what extent can a dance automated wheelchair help wheelchair users to practice physical exercises?

To answer this question we need to define a model or a framework to follow in assessing how helpful is the dance chair from different points of view. There are well known models that define
factors for user acceptance for a technology. Technology acceptance model (Chuttur, 2009) is a well known model which states that the user’s acceptance to a technology is based on usefulness and ease of use. We may also assess the acceptance of the dance chair from usability point of view. Usability is defined in ISO as "The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use". However, definitions of usefulness, effectiveness, efficiency and satisfaction are not the same for each technology. Efficiency of a software might be a function of learnability while in the case of the dance chair, learnability of controlling the chair with upper body muscles may take a long time and is not intended to be easy. In the following section we will examine specific models for assessing technologies.

**OUR MODEL FOR JUDGING ASSISTIVE TECHNOLOGIES**

When trying to fit the dance chair to technology acceptance model we find some limitations in this model to cover the participants’ opinions, experiences and concerns towards new technologies. In case of assistive technologies, technology acceptance can include more psychological and societal factors due to the nature of its users as a minority and due to the involvement of the government and hence the society in paying the cost of these technologies.

For example, participant 10 mentioned wheelchair students who received a robot arm connected to the wheelchair that helps them in everyday life. However, they didn’t want to use it because it looked big and strange and they are sensitive to the way they are viewed by others. They only started to use it when they saw more users accepting it. In this specific case, the technology acceptance model cannot explain why they didn’t accept the robot arm despite it was useful and easy to use. We will use the word ‘appeal’ to describe this factor.

Another salient factor that we need to add to the users’ acceptance is affordability. There was a common concern among participants about the affordability of the system. We cannot neglect the involvement of affordability factor in user acceptance specially that the government and society are involved in paying for these technologies. If the designer considers affordability as a factor in user acceptance, the design can be directed from the beginning towards a more practical alternative. This suggests the possibility to extend the technology acceptance model for assistive technologies by adding factors of appeal and affordability of technology. These two factors will be considered in implications on design section.

However, Model of system acceptability by Jacob Nielsen, shows to be more inclusive to the factors of appeal and affordability than the technology acceptance model. In this model, usability is part of system acceptability and not only the ease of use. The social acceptability may explain why wheelchair users refused a big robotic arm connected to their chair despite it was useful and easy to use.
After extending the technology acceptance model according to wheelchair users’ minds, experiences and concerns, we can reconstruct the research question to a more detailed one:

**How far a dance automated wheelchair be useful, usable, appealing and affordable for wheelchair users?**

Usefulness in our case includes physical, social and enhanced motivation to practice physical exercises.

**Usefulness**

It is difficult to say for the whole system and for every user if the dance chair will be useful or not. All participants agreed on the usefulness of the online social dance because people are becoming more social online and wheelchair users may be isolated inside their homes and because previous social networking sites and online gaming are already there and have proved success (4.1). Unlike
the other features, no participant mentioned a drawback of online social dancing. Online social dancing may be a motivation to practice exercises and socialize.

Fully automated movement was not appreciated by participants because the user cannot decide where the chair is moving (1.1) and because the muscles are not moving. While participants who appreciated a highly automated movements were aware of other types of users with high disability who rely on others to move the chair for them while dancing (1.6). therefore, a highly automated movement may be useful for this specific type of users.

Regarding controlling the chair with upper body muscles, some participants saw it useful because it stimulates muscles (2.3) and because it enhances the sense of achievement (3.4) and the learning progress may enhance motivation (3.3). On the other hand some participants saw a drawback of controlling the chair with upper body muscles because many users cannot precisely move their upper body (1.6). Dance design software was considered useful by some participants as it is a tool for physiotherapists to help users practice and stimulate specific muscles and an entertaining tool for creative users (5.1). While other participants considered it difficult and only few users may use it (5.1).

In general, the dance chair can be useful if it is well tuned for each user. The degree of usefulness depends on each person and is difficult to judge in this paper without a real prototype. The tradeoff between usefulness and price of the system is difficult to predict. The cost of bad tuning or poor usability may also challenge the usefulness of the system.

**Usability**

Usability of the dance chair is difficult to judge in this paper because the system is not yet implemented. However, defining usability aspects is important as a design guideline. The challenge of making a usable system for wheelchair users is that each user has different abilities and limitations. Jakob Nielsen defined factors of usability as learnability, efficiency, memorability, errors and satisfaction. The ISO definition of usability represents usability in effectiveness, efficiency, and satisfaction. We can use these definitions in assessing the dance design software. However, for assessing the usability of the chair movements, participants represented usability in ease of use, perceived safety, fitness to the user’s abilities and body extension (5.1,5.2,2.4). The flexibility of the system to be tuned according to each user appeared to be essential. The expression of “Body Extension” proved to be not only a philosophical or artistic expression but an expression that evolved from the participants’ lived experience with the wheelchair.

Therefore, the definition of usability for each type of technology may add new aspects to the traditional usability definition. In assistive technologies, we can add factors like fitness to the user, extension of the body and tune-ability to user abilities and limitations.

**Variance among participants**

In this study, each participant was focused on some point through the whole interview. If we read the interviews carefully, we can see that each participant had a certain theme and certain
tendencies in his/her opinions based on interests, background or personality. This may also be caused by limitations in interviewing style.

For example, participants 2, 3 who have artistic feeling for dance tended to be more focused on the feelings behind the dance in their views; they mentioned expressions like “music is in your heart, the feet doesn’t give you the feeling of dancing, the feeling is in your body, you dance in your mind”. As a result they admired the simple movement provided by the dance chair without speaking a lot about complex or specific details. They perceived the movements of the chair as a big help for users who cannot move their wheelchair.

On the other hand participant 6 who is an active sportsman compared dancing to sports. He admired that the dance chair can help users experience progress in learning new moves and become motivated by the feeling of achievement and improvement. He saw the journey of learning is more important than the destination and more important than dancing itself. As a result he appreciated the feature of controlling the chair with the upper body and he perceived it as a way to develop new skills in body movement.

Participant 7 who received a degree in human kinetics, was focused on the body aspects like balance and stimulating muscles and stimulating the brain. She admired the possibility of designing a dance as she perceived it as a useful tool for physiotherapists to stimulate specific parts of the body to do a desired function.

Participant 10 who is a teacher for students with special needs and seemed to be aware of psychology and human experience, was very focused on real user experiences with technologies and was very practical in her opinions and criticism. She perceived the movement of the dance chair as difficult and unpractical and difficult to adjust. She was aware of how modern technologies can be a load on users if they don’t add something important with the minimum effort. She admired only the social online dancing as it can motivate people to exercise together and meet online. She mentioned that people go to dance classes mainly for socialization but to do just exercises they have to be motivated in themselves.

The variance among users gave us a rich taste how and why each feature of the chair can be attractive or not to each specific type of users. In this sense the user acceptance showed to be a function of the user not only a function of the system. The definition of usefulness showed to be relative to each user experience and interest and again is not only a function of the system.

**IMPLICATIONS FOR DESIGN**

The insights gained from this research provided a better understanding of actual users. Each factor described in the results can be used to add a variable in the system as following:

1. Regarding control, it was clear that most of the users prefer to be more in control as long as they can, while fewer users who cannot control the chair for physical reasons will appreciate a more automated system. As a result on design, features 1 and 2 shouldn’t be separate but a continuous tuning between automation and free control based on the user’s abilities. (see factors 1.1, 1.6)
2. The speed of the movements should be slower and controlled as a parameter of the system based on the user’s abilities to balance oneself in the chair. (see factor 5.3)
3. There is a need to inform the user about every movement enough time before sending signals to the motors. (see factor 1.2)
4. The chair should follow the instructions of the user’s body posture without much restriction and if needed informs the user about the correctness of the body posture. (see factors 1.4, 1.5)
5. The system should show the user ones progress as this was shown to be an effective motivator. (see factor 3.3)
6. As a starting step in the design, the movement factor may be left for later improvements to implement the system in an easier steps while putting more effort in the social aspect and the body posture measurements and simulations. (see factors 1.1, 1.6)
7. Regarding online social interaction, it can be useful to share the social dance online with both wheelchair users and also able bodied dancers. (see factors 4.2, 4.5)
8. The sensors in the system may be connected to gaming tool like Wii and xBox to share the dance with already designed dance games and to share it with able bodied users as well.
9. The dance designer software needs to be simple and easy to use with graphical interface. (see factors 5.1)
10. The apparatus should be small, simple and easy to connect to the wheelchair and the PC. (see factor 5.2)

**LIMITATIONS OF CURRENT WORK**

In this qualitative study, we tried to take the first step towards understanding the users’ attitudes and opinions towards a future technology. After finishing the research and analyzing the results, we can see some of the limitations in the current study:

1. The video prototype shown to users is not clearly showing realistic moves of the chair but a marionette chair with a doll on it, therefore the users are asked their opinions based on an unrealistic model.
2. Participants are selected randomly and their opinions are mixed without separation based on disability type or their role in wheelchair dancing. Many opinions were clearly variant because of the variance in users while this is not kept in mind.
3. The interview questions might be biasing a bit. For example, asking a question like “Is it motivating?” might bias the participants’ opinions towards a positive direction despite we informed participants to be opened and unbiased.
4. Some interview questions were not asked to all participants because we discovered the value of these questions in the second interview. For example, “What do you think about removing the movement from the system”. There was a need to perform few pilot interviews before collecting the actual data and reconstructing the interview questions.
5. Through the interviews we discovered that a group of opinions may belong to usability of the system. However, there was no previous intention to define questions related to usability as a well defined group of interview questions.

6. The interview questions were not based on previous work or theoretical framework, but were more based on features and our understanding to these features. May be following a group of models or framework might have helped in creating a richer and deeper interview.
FUTURE WORK

This qualitative research has two major goals:

1. Defining a deeper questionnaire to answer the “How much” question; how many participants like each specific aspect and to what extent and what is the relation between their opinions and other dependent variables.
2. Defining better recommendations for designing the technology based on users’ opinions and impressions.

Therefore, for future work we recommend creating a better video prototype or real prototype based on the design recommendations mentioned before and creating a questionnaire as described before. In this sense, a deeper and more realistic understanding of the acceptance and preferences of users can be assessed clearly.

DEFINING A QUESTIONNAIRE

One of the goals of this research is to define a questionnaire for future work. A quantitative questionnaire can be defined from the themes discovered before. For each factor, a survey question can be defined with Likert scale. For example, factor 5.3 speaks about movement speed, hence a question in the survey can ask participants about how fast they think the movement in the video is. In addition, deeper questions about demographics and personal preferences can be extracted from the results. For example, questions about the level of spinal cord injury may help in defining the balance abilities of the user based on Factor 1.3. In this way, a deeper understanding of the variance among users will be easier.
BIBLIOGRAPHY


APPENDIX 1: TECHNICAL DETAILS FOR CONSTRUCTING THE DANCE CHAIR PROTOTYPE

SYSTEM SETUP

A body posture sensor network is implemented on the seat of a power wheelchair. The wheelchair is connected to a PC through its control unit. The PC has special software that processes the received signals from the body posture sensors and decides based on a pre-designed interaction scheme which movement patterns it should send to the wheelchair to move accordingly. Hence the technical development can be divided into 3 parts:

- Part one: designing a new control unit for the wheelchair that can be connected to the PC and can control the wheelchair in the required speed without many restrictions.
- Part two: designing a body posture sensor network and its control unit that gathers information and sends it to the PC at a suitable rate.
- Part three: designing a special software that enables the user to design a favorite dance by uploading a music video to the program and defining a series of interactions that the chair should perform based on the music timing and body posture.

PART 1: WHEELCHAIR CONTROL

WHEELCHAIR CHOICE CRITERIA

The first step is to purchase a suitable power wheelchair. Based on our application and costs limitations, the criteria for the wheelchair include:

1. Low price and low transportation costs: we could purchase a used wheelchair in a sufficiently good condition for 400 euros.
2. Good condition of motors and fast response of motors: this was simply tested at the store by applying sudden triggers to the joystick and observing the chair response.
3. Good condition of batteries: this was tested using a voltmeter where the chosen chair batteries showed over 12 volts. The batteries should be left outside the charger for a night before performing this test but this was not possible to test before buying the chair.
4. Ease of communication to a PC: as most of the wheelchairs in the market use control units from one manufacturer (Dynamics Control Corporation), we didn’t have many choices. It was very difficult to search the internet for the manufacturer of the control unit for each chair manufacturer and few articles mention information about the interior of wheelchairs.

Based on these criteria, we purchased a second hand puma power wheelchair after testing a number of available options.
EXPLORING THE WHEELCHAIR

The wheelchair consists of 2 geared motors model Parvalux PM63 with the following specs:

- Gear ratio: 25
- Output Speed: 219 RPM
- Nominal output torque: 8 Nm
- Power: 200 watts at 24 volts

The amperage is not mentioned as it depends on the load but searching the internet, we found that similar wheelchair motors use around 16 Ampere of average load current. The motors are fitted with electromechanical disc brakes on their shaft. The braking system consists of a friction disc connected to the rotating shaft and a stator disc that is held in contact with the rotating disc by a force generated from 3 springs. The stator disc is released away from the rotating disc using a coil that creates a magnetic field to pull the stator disc away from the rotating disc. The coil is activated by applying 12 volts has to it. The 2 coils of the 2 brakes of the motors are connected in series and draw around 700mA for both brakes to be released.

The motors don’t have encoders so they are controlled in an open loop. The chair is fitted with two 12 volts batteries connected in series through a power switch. The control unit is manufactured by Dynamic Controls (www.dynamiccontrols.com); a company specialized in wheelchairs control units and joysticks. There is one control unit for the motors and extension module for the lights and seat positioning. The control unit uses a proprietary protocol called DX based on the industrial CAN BUS for communication between the joystick, the control unit and the extension module. The architecture of the connections is described in the following figure.
CONNECTING TO THE DX CONTROL UNIT

The next step is to connect the wheelchair control unit to the PC. Dynamics Control Corporation is the manufacturer of the control unit as well as a wide range of other wheelchairs’ control units. As a result we didn’t have many choices in choosing a wheelchair based on its control unit. We tried to find documents describing the DX bus protocol but unfortunately it is proprietary based on CAN BUS physical layer. The option of hacking the DX bus and listening to the messages transferred between the joy stick and the control unit was excluded for several reasons. First, a CAN BUS to serial converter is quite expensive around 130 euros because of its industrial nature. Second, we are not sure about the results and the ease of fully understanding the transferred messages. Third, the microcontroller might have strict strategies in controlling the motors for possible safety reasons which might limit the desired control of motors for the purpose of dancing. Forth, there might be some fail safe procedures implemented by the manufacturer to stop the chair if the communication is not correct which might cause a sudden impact on the user. Therefore we thought it is a better choice to implement our own control unit that can be connected to a PC.

CIRCUIT DESIGN

The following circuit diagram describes the root design. Starting from the left the battery connector feeds both 7805 and 7812 that power the logic circuitry and the relay coil respectively. The relay output feeds the FETs positive through fuses and also feeds the 7815 to power the FET driver. The PIC16F1829 is in the centre of the figure. It controls each of the motor drivers through 2 signals. At one direction one signal acts as the PWM and the other is driven low and vice versa for the other direction. Each motor driver module is connected to the battery positive through a 20A fuse. The 7815 feeds the 3 modules with 15 volts for the HIP4082 driver. The microcontroller switches the relay though a safety switch then a relay driver NUD3112 which pulls one relay terminal
to ground. The mechanical brakes are driven high by the microcontroller through 2 high side inductive load drivers ISP762T. One driver for the seat motor brake and the other for the 2 wheels motor brakes that are connected in serial. Finally the microcontroller communicates with the PC through its USART peripheral and the low voltage is shifted through a max232 serial driver.
PART 2: BODY POSTURE SENSORS

A body sensor network is needed to sense the user’s posture position. There are many different possible setups of sensors that might be used to measure the body posture. However, in this project we are limited with some criteria:

1. Since the user is disabled in the lower body and sitting on a chair, we only measure the upper body posture.
2. The measurements must be taken while the user is seated on the chair, therefore it is relative to the chair position.
3. The sensors need to be attached to the chair as much as possible with limited connection to the user’s body for practical reasons.

In the current project we focus on the main movements that can be done while seated including the upper body leaning position relative to the chair and the shoulders position relative to the seat back. For future work, more sensors might be added for more complex position measurements.

CHOICE OF SENSORS TYPES

Based on the mentioned criteria the following sensors were chosen:

1. Four shear beam load cells carrying the seat at four crossing points to detect the user’s leaning to the front, back, right, left and the product of these directions. Each of the load cells were chosen to carry 120 Kg to support a maximum leaning on one side of a user that might reach 120 Kgs in weight.
2. Two distance sensors behind the user’s shoulders to measure their distance relative to the seat back. Searching for accurate distance sensors within the required small distance range, ultrasonic sensors were not an option as they are not accurate at small distances. We found infrared sensors by Sharp that can have highest accuracy in the range of 4cm to 30 cm.

3. Two accelerometers (3 axis) connected to the user’s sides using a rubber belt to measure other possible movements of the hip bone and abdominal muscles. We chose a 3 axis 1.5g micro machined accelerometers by Freescale Semiconductor for their low price, small size and low range which means that it has a high amplification for the small movements of the hip bones.

The results of this configuration were difficult to expect before testing. So part of the choice criteria will be based on testing the results of these sensors and their support to the desired application.
PART 3: PC SOFTWARE

A PC software was developed to control the whole system and synchronize the motor movements with music and body movements according to a sequence designed by the user and saved in a database. The software has one window with 4 tabs that represent the main components of the software. First, the figure design view; where the user defines a number of figures and defines the actual motor movements associated with each figure. Second, the choreography design view; where the user designs a dance by defining a sequence of figures that should be played at a specific beat timing in the video. Third, the dance floor view; where the user can watch a dance video while the software, translates the designed dance choreography and sends the correct signals to the motors at the right timing. Each view will be explained in details in the following sections. The software is programmed in C# and the designed dance sequence is saved in a SQL server database.

FIGURE DESIGNER VIEW

In this view the user can define a “figure”; a sequence of steps of the motors that define a basic unit of dance. The “list of figures” are shown in the upper grid and the sequence of moves of the 3 motors associated with each figure are shown in the lower grid labeled “Figure Design”. Each row in the figure design grid is defined by each motor’s direction and speed and the starting beat timing. For example, in the following print screen of the software, a figure called “zouk slow left turn” consists of 7 steps. In this figure the chair should turn one complete turn to the left around it’s center. The first step is defined by a starting “beat” of zero and the speed and direction of each motor. The second step is defined by starting beat of 0.2 and the speeds and directions of each motor. Let’s say that the dance tempo is 60 BMP (beats per minute). When the dance design requires playing this figure, the software sends the wheelchair control unit a message to change the motors speed and direction according to the first step. After 0.2 beat period, the software finds in the database a new step definition. So after 0.2*beat period (here it is equal to 1 second), the software will send the chair a new message containing the new values of speeds and directions of the 3 motors. The chair control unit will immediately change the motors’ speed and direction accordingly. This process is repeated for 7 steps according to this example. It will take the chair 1.75 seconds to finish this specific figure. All these data are defined by the user and saved in the database. The exact algorithm behind this sequence will be described later. This view is shown in the next figure with the example figure appearing in the print screen.
In this view the user designs a dance choreography (see next figure). First, the user defines a new dance in the upper grid labeled “List of Dances” by specifying the dance video file URL and the dance tempo and other parameters. The dance video is displayed in a small media player panel on the right. To calculate the tempo, the user can press a button labeled “Press on beat” when hearing the tempo. The software shows the calculated tempo. When the user pauses the video at any moment, the software shows the elapsed time of this moment in millisecond precision. This value is used to define the start point column in the upper grid which is the value of milliseconds in the video at which the system will start counting the beat. Obviously, both the tempo and the start point values will not be accurate from the first time. After saving these values in the grid, the user should play the video again and visually observe the changing value of the “Beat” field and check if it is leading or lagging the music beat and accordingly adjust the values again until the visual and audible beats are matching. By trying 3 songs this process took few minutes of try and error to adjust.

After adjusting the dance video parameters, the user fills a list of figures that will be played in this dance choreography design in the lower grid labeled “Choreography Figure List”. Each figure in the list is defined by the starting beat timing and the number of times this figure will be repeated. The grid has a combo box that lists all the names of figures defined in the Figure designer view. The user can play each figure on its own within the part of the video that it should appear in.
DANCE FLOOR VIEW

In this view, the system plays a selected dance video and executes the algorithm that moves the chair according to the choreography designed by the user. This view is composed mainly of a big video player panel displaying the dance video. Under this panel, a clear text box shows the name of the current figure and the number of repetitions left. In the figure shown, the current figure name is “Zouk basic in place” and it will be repeated for 7 times.

CONCLUSIONS

From the technical point of view, the system works precisely in integration. However, the involvement of the human body in the control loop of this system requires more adjustments and considerations than in simpler types of control. Measuring the precise body position is challenging due to the differences between bodies and the flexibility of the human body. The requirement of
this research to make a wheelchair that can dance in a flexible way challenges the current design of the wheelchair motors and requires more powerful and smooth motors with feedback control. The motors’ response needs many adjustments to feel more comfortable to the user as a normal movement from zero to medium speed feels a bit aggressive and uncomfortable. As this document focuses on the technical side, the human experience in using this system is left for experimentation and will be recorded in another document.

For future work, there are some considerations that we learned to put in mind. Regarding motors’ control, they need to be slower and more powerful by having a higher gear ratio. In this application, high speed motors are not needed compared to the speed of wheelchair mobility solutions. It is essential that the motors are feedback controlled for both speed and position control. The motors’ movement has to be adjusted carefully not only to reach a desired position or speed, but to present a comfortable and smooth movement experienced by the user. This needs a try and error of different speeds and accelerations for different users. The seat rotation while the chair is moving adds more instability because the center of gravity of the user body is not constant relative to the chair base. To compensate this, there is a need to increase the size of the base to provide a stable movement when the seat is rotating in all directions.

Regarding the sensors, we found that the load cells and the IR distance sensors are efficient enough but still need some compensation in software to manage different cases that might give misleading values. For example, when the chair moves in one direction the user body leans to the other direction due to inertia. In this case the system will falsely interpret that the user intentionally moved to that direction. Therefore there should be some integration between the measured body posture and the chair movements at the moment of measurement. In another situation, the shoulder movement measured by the distance sensors need to be mapped in a different way because the shoulder movement is not perpendicular to the seat back all the time but is moving in a round manner around the vestibular column. Therefore a better way of mapping should be put in mind while using the distance sensors as an indication for the shoulders’ position. To make use of the accelerometers, More effort should be put in transforming their output into meaningful value. The chair movement is already causing some effects on the accelerometers. Therefore, there is a need to add an extra accelerometer to the seat and subtract its measurements from the ones attached to the user’s body. In addition, the values from the 3 axes has to be processed to extract the equivalent movement in the plane of interest.

Regarding software, the current interface needs more improvement so that the user doesn’t need to write the desired dance choreography in database tables but in a more graphical intuitive way close to the user’s mental model. The tempo calculator needs to be automated through music analysis which is possible by integration with other software.

The success of this design is highly dependent on users’ opinions and perception when using the system. The system can be highly adjustable based on user’s experience and preferences. This makes it very difficult to assess the success of the system as a whole from the user’s point of view but we can only assess it from the technical point of view. Another project is dedicated for testing the system by interviewing a number of users and asking their opinions from different points of view.