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DEMONSTRATING A METHODOLOGY FOR OBSERVING AND DOCUMENTING HUMAN BEHAVIOUR AND INTERACTION

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1. Introduction

In 2008 more people were aged over the age of 60 than under 18 years of age in the United Kingdom [Nichols et al. 2006], and in 2010 more than 20% of the populations of Germany and Italy were over 65. By 2066 it is predicted half a million people in the UK will be over the age of 100, and this reflects European trends [Osman et al. 2003]. Ageing is associated with a decrease in mobility and social interaction, and this can have detrimental effects upon access to good nutrition, leisure and other activities. Increasing the mobility of older adults increases opportunities for social interaction and can have positive effects upon individual health and well-being [Muller 2002]. Shopping is a useful way for individuals' to engage in physical activity and social interaction. However, older adults may be less confident in their ability to go out independently in unfamiliar and crowded spaces due to fears over safety and falling [Tinsley and Weiss 2000]. In 2011 the Devices for Assisted Living (DALi) project explored the development of technological solutions to shared space navigation through the development of an intelligent mobility aid that was intended to aid a user's seamless navigation of shared space whilst minimising the possibility of collision.

The experimental work presented in this paper reflects preliminary attempts to determine an appropriate methodology for observational studies, and to gain an understanding of the technological requirements in terms of experimental data capture. An initial aim was to capture the characteristics of interaction and develop an understanding of the behaviour that occurs in confined environments: how people consciously negotiate and interact in shared space. The expectation was that such knowledge might contribute toward the long-term development of system intelligence in the form of a behaviour prediction engine. Twenty-five students from the University of Trento, Italy, therefore participated in a simulated shopping task to verify that an appropriate methodology had been developed to reveal human thought, decision making, and behaviour, during shared space interaction. This experiment was seen as an incremental and exploratory step toward conducting larger studies based in the laboratory and in more ecological environments to guide system development (Figure 1).

Figure 1. Intended incremental steps to inform the Design and Development Process

2. Inclusive, Participatory and User Centred Design

User-Centred Design, and more specifically Inclusive Design, is itself, an approach that aims to create interfaces, artefacts, products, and services that are applicable, appropriate, and accessible to as many users as possible within the constraints of the design specification [Keates and Clarkson 2003]. Also referred to as *Universal Design*, it attempts to optimise both product and service design for maximum accessibility and make '*…mainstream design accessible to everyone'* [Population Trends 2010]. The intention is that such an approach will provide salient solutions; solutions that work as effectively for less able users as they do for more able users. Under the same umbrella, but with a slight twist, Participatory Design aims to develop technologies with the close involvement of stakeholders and end-users through cycles of requirements gathering, prototype development, implementation, and evaluation [Sanders 2002]. To inform the design and subsequent development process, it is important to capture user information and feedback ideally at every stage, with input from everyone involved; users, designers, and the remaining stakeholders. Such an inclusive participatory design approach, then, can be seen as an attempt to better understand and involve people throughout the design process, and as imperative and important in creating more appropriate, applicable, and user friendly products or services [Lim et al. 2005], [Lindgard et al. 2006]. This echoes Sanders [2002] notion of Participatory Design as a belief that *all* people have something to offer *at every stage* of the design process and that when given the appropriate tools with which to express themselves, they can be both articulate, creative, and inspirational, in terms of generating new ideas and in developing current thinking [Rouse and Morris 1986].

The overall objective of the DALi project was to increase the autonomy and independence of older or impaired people. Increasing personal mobility with the aid of an inclusively designed intelligent navigational system was therefore seen as a key factor toward this aim. In this context, understanding what shopping means on an individual level to people and what it involves, being able to predict likely behaviours in shopping or congested environments, and observing the effect of walking aids and older people on other agents in the environment, all play an important part in increasing our understanding of the task and influences the development of subsequent design solutions. This participatory design approach would aim to better understand the diverse needs and requirements of an older demographic by involving them within a process that fosters and develops knowledge acquisition for the design community. Ethnographic observation of older users would also provide useful additional insights into the approaches utilised by older people when shopping, whilst structured interviews and discussions would attempt to elicit how older users approached the task, and determine factors that may make this task easier.

3. Methodology

The initial sample for the pilot study was selected from the university student population to reduce reliance and pressure upon older individuals during the methodological verification process. However, the long-term intention remained to involve a more representative sample of users to glean design insight that might be more demographically informative. Indeed, the pilot study helped determine how such an approach may be transferred to more ecologically valid environments and settings that were envisaged for the future work involving older adults. One key advantage of establishing such a controlled approach was that it ensured the development of a repeatable procedure that could be implemented within later evaluative studies without compromising participant safety.

In terms of humanistic shared space interaction, this study aimed to investigate three main themes:

- How do people interact in confined environments?
- How do people negotiate shared space?
- How do people behave with other agents in shared space?

In the context of the prediction engine, the long-term aim was to represent the above information algorithmically in order to inform its development. However, the experimentation also assisted in gaining knowledge regarding the social and goal-oriented drivers of shared space interaction.

3.1 Data Capture Techniques

Specific techniques were identified and selected for use in the study, as their ability to obtain objective data in such scenarios is well documented [Muller 2002]. Data capture thus involved the use of:

- Concurrent protocol provided by participants whilst completing tasks
- Video-recorded observation of interaction and behaviour during task completion
- Questionnaire completion after task execution

These techniques have been found to be particularly effective when conducting experimental investigations [Rogers and Fisk 1997], [Jarke et al. 1998]. The concurrent protocol – a narration of thought and action – was chosen as literature suggests that the alternative retrospective protocol where participants return to view and comment upon their recorded experience may not reveal participants actual task performance experience [Hands et al. 2001]. Furthermore, participants performing concurrent protocol have been found to go into greater detail and provide more in-depth evaluations [Sharma et al. 2008].

The voice-recording functionality of five HUAWEI U8650 Android mobile phones was utilised to capture each participant's concurrent protocol. Three Logitech Quickcam Pro 9000 webcams recorded the interaction within the 12m x 12m simulated shopping environment. These images were then coordinated to provide a comprehensive view of the interaction space (Figure 2).

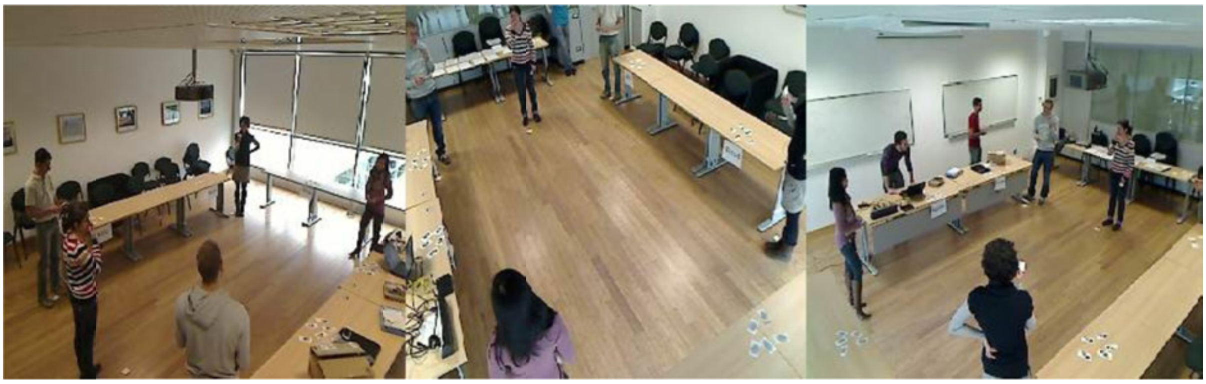

Figure 2. Digital capture of shared space interaction

The recorded video-data was analysed to identify how the concurrent protocols corresponded to participant behaviour, to identify task completion times, and identify the number of steps taken toward task completion. This was possible with the use of the Elan tool [Elan Annotation Software 2012] that facilitates the creation of annotations on video media (Figure 3). The protocol for each participant was transcribed and synchronized to the footage, and this permitted the identification of critical instances. Such instances were defined as instances where physical, visual or auditory reference was made of agent-to-agent interaction within the footage. Due to the preliminary nature of the study, these instances were determined by a single independent reviewer. However, in the subsequent investigations the importance of inter-coder reliability would be emphasised to maximise methodological rigour (see [Chi 1997], [Tinsley and Weiss 2000]).

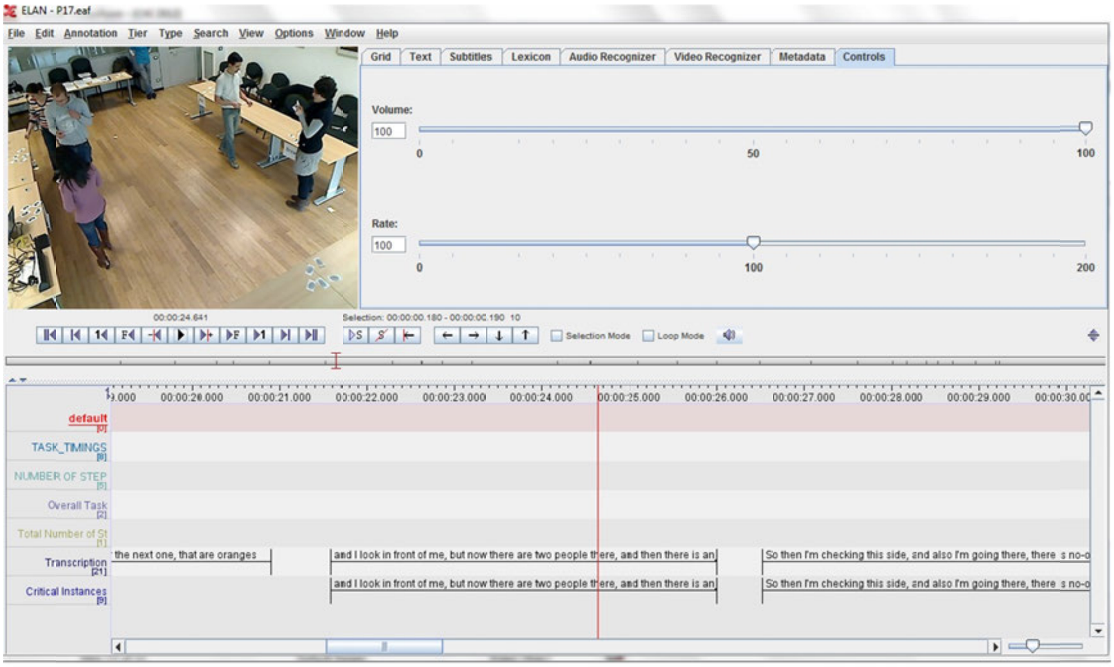

Figure 3. Elan software tool used to annotate video footage

The subsequent questionnaire material yielded further data upon participant's approaches to shopping and their interactional behaviour. The open questionnaire covered the following topics:

- What do you feel most contributed to your awareness of other people in the shared space?
- How did you approach the task of buying the products?
- How did you avoid others in the environment?
- Did you consider social rules whilst engaged in the activity – if so, what rules applied?

3.2 Experimental Design

The experimental design aimed to capture information regarding how people interact in confined environments, how they negotiate shared space interaction, and how they behave in relation to other agents in shared space. The participant sample consisted of 25 university students. Each participant was recorded whilst involved in a shared space interaction task. 20 of these participants also completed a post-experimental questionnaire regarding their shopping behaviour. The overall sample consisted of 6 Females and 19 Males.

5 participants were involved in each experiment, and assigned a list of four shopping items to collect:

Participant 1: Milk, Apples, Bread, Pizza
Participant 2: Bread, Oranges, Pizza, Milk
Participant 3: Oranges, Bread, Milk, Apples
Participant 4: Apples, Bread, Oranges, Milk
Participant 5: Apples, Bread, Pizza, Oranges

Participants were arranged specifically around the simulated shopping environment and each of the five shopping lists were designed to maximise shared space interaction. The potential route-behaviour of participants 1 and 4 are represented below (Figure 4).

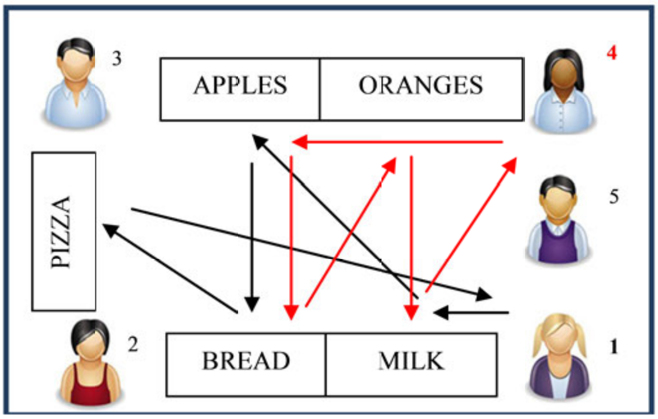

Figure 4. Experimental set up of shopping items and potential trajectories

Each participant collected the items on their list and returned to their starting points whilst verbalising their shopping experience. These protocols included descriptions of what they looked at, what they saw, where they went, and what they were thinking, seeing, and doing.
Paper-based materials were developed to represent each of the shopping items with images of each item placed in the locations depicted in Figure 3. The shopping lists were similarly developed and distributed to each participant. Three Logitech Quickcam Pro 9000 webcams recorded the overall shared space interaction, and 5 HUAWEI U8650 Android mobile phones were used to record the verbalisations of each participant's navigation of the 12m x 12m shared space.

3.3 Data Analysis

The concurrent protocols once transcribed and synchronized with the video footage facilitated assessment of a number of variables including Task Completion Time, Number of Steps taken, and the Number of Critical Instances (Table 1). Critical instances were defined as instances where physical, visual, or auditory reference was made within the verbal protocols regarding agent-to-agent interaction. The questionnaire data was utilised to reveal knowledge regarding participant shopping strategies and key factors within agent-to-agent and agent-to-environment awareness.

Table 1. Variable Coding Schemes

Individual Task Completion Time	From start to completion of task 1 From completion of task 1 to completion of task 2 From completion of task 2 to completion of task 3 From completion of task 3 to completion of task 4
Overall Task Completion Time	From start to when participant returns to start point having completed all tasks
Number of Steps taken to complete individual tasks	From start to completion of task 1 From completion of task 1 to completion of task 2 From completion of task 2 to completion of task 3 From completion of task 3 to completion of task 4
Number of Steps taken to complete overall tasks	From start to when participant returns to start point having completed all tasks
Number of Critical Instances	Instances where physical, visual and/or auditory reference was made within the verbal protocols to agent-agent interaction

An analysis of the video and critical instances data was conducted to examine the behaviours that occurred and that were referenced within the verbal protocols according to the above definitions. The emerging themes allowed the categorisation of shared space interaction according to active or reactive behaviours, and these are explained in greater detail within the following Results Section.

4. Results

The examination of the time taken to complete tasks per task order, the number of steps taken, and the number of critical instances observed, all contribute to our understanding of interactional behaviour.

4.1 Task Completion Time, Number of Steps Taken, and Number of Critical Instances

An analysis of variance showed no significant effect of Task Order on Task Completion Time $F(1, 38) = 415.833$ $p>0.05$, Number of Steps Taken $F(1, 38) = 229.400$ $p>0.05$, or Number of Critical Instances $F(1, 38) = 0.771$ $p>0.05$. That these factors were not significantly affected by task order indicates that no single individual, or groups of individuals, experienced a greater number of interactional or negotiational issues than any other.

The purpose of capturing this data was to pinpoint the instances within each individual's experience where they interacted directly with others in the environment. Thus, the results of the preliminary investigation indicate that the methodology was capable of capturing quantitative data to monitor the movements and effects of agents within the shared space. Further, it facilitated examination of the behavioural and negotiational techniques employed by participants. Successfully developing a method to document common behaviours that might be expected in social situations such as shopping was intended to add a dimension of social intelligence to the mobility aid and, overall, confirmed that the approach was worthy of development using older people and more ecologically relevant environments. Results of further study should then be able to inform the development of an intelligent mobility system that facilitates interaction and avoids collision within a range of environments.

4.2 Behavioural taxonomy development

Using the critical instance markers from the transcribed protocols synchronised to the video footage, it was possible to document the behaviour exhibited by participants when involved in shared space interaction. Critical instances were defined within the verbal protocols as references to physical, visual or auditory agent-to-agent awareness or interaction. Analysis of these critical instances revealed a number of common themes and behaviours. The themes that emerged indicated that the behaviour itself was usually employed to either negotiate shared space interaction or avoid collision within the shared space. Further, it was possible to categorise these main types of behaviours in two groups: Active and Reactive behaviours.

4.2.1 Active behaviours

Active behaviours were considered to be behaviours employed to understand the environment and determine goal strategies toward task completion, environmental awareness and negotiation, mainly focussing around the visual modality:

1. Eye-to-eye negotiation of immediate shared space interaction
2. Use of peripheral vision in assessment
3. Visual scanning of environment
4. Verbal interaction

4.2.2 Reactive behaviours

Reactive behaviours were considered as the reactions of agents in the environment to other agents; the physical reactive movements made to accommodate other agents and successful interaction:

1. Waiting for free space or desired location to become clear
2. Stepping backwards to allow others more room/free space
3. Moving forwards to allow others more room/free space
4. Stationary agent yielding to moving agent
5. Move left
6. Move right

Table 2 provides an example of how the critical instances were interpreted in terms of the above taxonomy of behaviours observed during shared space interaction.

Table 2. Analysis of observed behaviours during critical instances

Participant X (PX)	Observed Behaviour / Reaction
Critical Instance Sequence 1	PX aware of other agent in desired space, elects to wait until other agent completes task [Jarke et al. 1998], [Hands et al. 2001], [Lindgard et al. 2006]
Critical Instance Sequence 2	Backward glance helps peripheral vision locate a participant directly behind PX and helps PX avoid collision [Elan Annotation Software 2012]
Critical Instance Sequence 3	PX becomes aware of an existing agent in front of them, and another approaching agent in the environment [Hands et al. 2001], [Elan Annotation Software 2012]. PX watches the actions of the moving agent and remains still, until the moving agent is passed, then collects the desired item [Jarke et al. 1998], [Lindgard et al. 2006]

Critical instance behaviours appeared motivated by social rules – waiting for spaces to become less congested, moving to create free space, and yielding to other agents in the environment (Figure 5).

Figure 5. An example sequence of Critical Instances

In the sequence reproduced above, two agents within the same shared space are observed waiting and yielding to a third moving agent that enters the space before continuing with their own shopping activity (left-to-right). Stationary agents yielding to moving agents was a common behaviour observed in the study. Participants used the visual modality to engage in scanning of the overall environment (usually to identify a product's location within it), or peripheral vision to monitor the movement of other agents. As proximity to others increased, eye-to-eye contact or negotiation between participants increased. Similarly, verbal negotiation was also evident in a small number of cases (Figure 6).

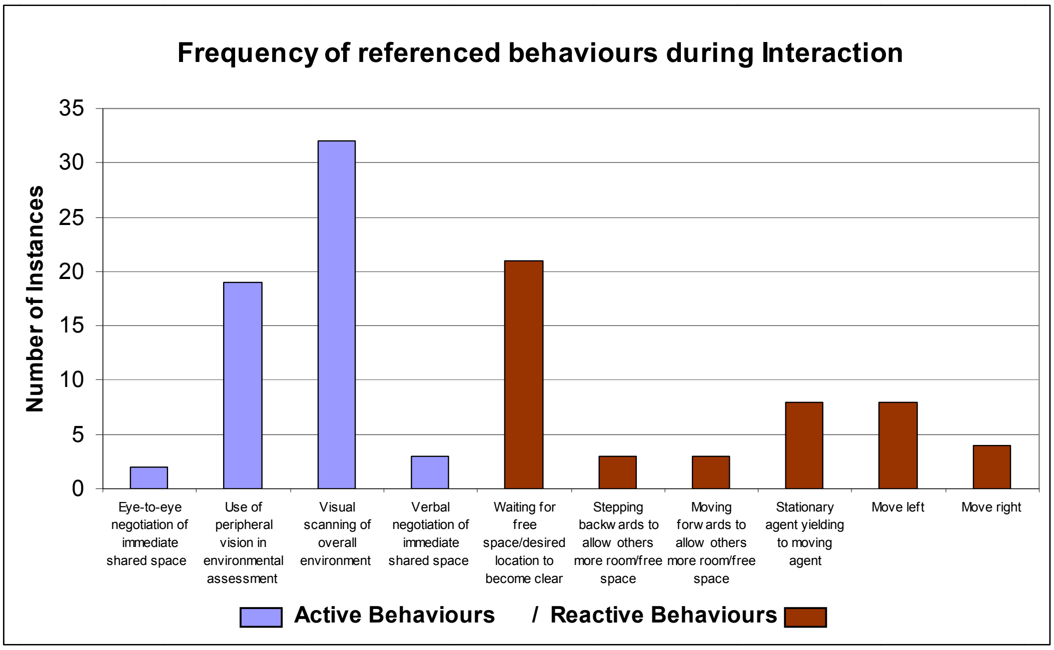

Figure 6. Critical Instances in terms of observed Active and Reactive Behaviours (n = 20)

The most commonly occurring reactive behaviours were waiting for free space to become available, moving agents given priority by stationary agents, agents moving to the left and right, and agents moving backwards and forwards to create free space.

4.3 Questionnaire Data

The questionnaire data confirmed that the visual system was fundamental in terms of understanding the scenario and indulging in shared space interaction and negotiation. The behaviour observed largely consisted of scanning the provided list of items, scanning the room to determine overall item locations, and making decisions on product choices according to participants' physical proximity to item location and shopper or crowd density:

- 32% (n = 25) elected to shop directly according to the shopping list
- 68% (n = 25) deviated from the list provided
- 60% (n = 20) referenced either direct eye contact or the use of peripheral vision
- 55% (n = 20) of participants reported awareness of Social Rules
- 50% (n = 20) reported applying Social Rules

5. Discussion

This study aimed to identify and demonstrate a methodology for observing human behaviour and interaction in shared space, to gain an understanding of the technological requirements in terms of experimental data capture, and in so doing, aimed to investigate the following research questions:

- How do people interact in confined environments?
- How do people negotiate shared space?
- How do people behave with other agents in shared space?

Within shared space interaction, social conventions appear to be observed and the visual system appears a key factor in terms of product determination, agent awareness, and collision avoidance strategies. In this simulated environment, participants used eye contact and peripheral vision to facilitate interaction with other agents. However, it is acknowledged that the recording mechanism did have the potential to affect the verbalisation of agent-to-agent negotiation. Shopping for convenience appeared to exert an influence on shopping behaviour with a significant proportion of participants deviating from the list provided. Having initially observed the location of all items, participants often proceeded to shop, either for the nearest items, or to avoid other participants positioned at shopping stations, returning later. Finally, a taxonomy of individual behaviours as a focus for the prediction engine was successfully developed according to the behaviours observed.

Determining in this study what the most frequently occurring responses were during interaction permitted the contemplation of how similar findings might be used in the future, should the developed studies yield similar results. This study also revealed consistencies in approach that included scanning the list of required items, scanning the shopping environment to determine overall item locations, and making decisions on product choices according to participants' physical proximity to them, and shopper or crowd density. Together, these results will contribute toward the probability engine's development with the use of Helbing's [2002] Social Force Model [Helbing et al. 2002]. This model represents human behaviour in the presence of obstacles and other people, and permits algorithmic simulation and modelling of several aspects of people and the environment. It recognises that, as in the real world, individuals attempt goal achievement via the most efficient and economical route, and that the presence of obstacles and other people may influence this motion and behaviour.

Finally, consideration of the context of use is paramount if the device will be used to help users achieve multiple aims such as navigating congested environments whilst shopping. These factors alone will have a direct impact upon the physical design of the mobility aid. Any display system incorporated must be of sufficient size and must accommodate older individual's visual and physical capabilities [Pullin 2011]. Screen or display illumination, if used, must also be considered due to the variation of environments in which such a device might be operated, and the design of man-machine interface itself must be sympathetic to the fact that manual dexterity often decreases in old age and impacts upon ease of use for older people [Office for national Statistics 2008].

6. Limitations and Future Work

The findings presented are limited to the laboratory study itself, and should not be considered outside of these boundaries. As mentioned, future studies will involve a wider demographic and the intention would remain to include older able-bodied and less-able bodied participants, both within experimentation and also within the larger participatory design process. However, as a preliminary exploration into shared space interaction, the methodology developed was successful in gleaning relevant data that might later be used to inform the development of the desired behaviour prediction engine. That the methodology was capable of identifying differences in individual approaches to the shopping task was a significant feature.

Further research is ongoing with the involvement of tracking technology that permits a more scientifically accurate and consistent indication of when two, or more, agents share the same direct interactional space and may be used to explore the exact behaviours exhibited and employed (see http://www.ict-dali.eu/dali/news.html). The reliance upon eye contact and the use of peripheral vision suggests that further exploration of visual behaviour at a micro level using eye-tracking and individual scene-capturing solutions to understand what each participant in the real or simulated environment attends to in their personal field of vision would also be valid.

Observing and documenting how people behave in a controlled environment will assist and inform the prediction of potential behavioural responses. By predicting the potential behaviours of other agents in the environment, and simulating the environment itself, it will be possible to determine a route offering the least resistance to the user, aid the user's seamless navigation of the environment, and minimise the probability of collision with the environment or other users of shared space. Participant involvement within the larger design process will also ensure the finalised design solution will work as effectively for less able users as they do for more able users. This methodology, then, can be seen as an example of how to better understand and involve people throughout the design process to ultimately create more appropriate, applicable, and user friendly products, systems, or services.

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