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LONG PAPER

Facets of prior experience and the effectiveness of inclusive design

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Abstract Research in inclusive design has shown the importance of prior experience for the usability of interactive products. Prior experience, however, is an ill-defined and inconsistently used construct. A number of different definitions and operationalisations of experience exist, but the differing power of these operationalisations to predict the usability of products for older users has rarely been investigated systematically. This study seeks to fill that gap. It is argued that the construct of experience has at least three components. It is proposed that two of these components, exposure and competence, are directly relevant for the current discussion about prior experience in inclusive design and that they can predict to different degrees the usability of a product for older users. In an empirical study, these facets of expertise are each operationalised on three levels of specificity and their impact on usability is assessed. The results show that measures of competence predict usability variables more strongly than measures of exposure and that levels of medium and high specificity are the best predictors. The application of inclusive design principles to a redesigned version of a ticket vending machine—although not resulting in a difference of overall usability—changed the *impact* of prior experience on usability measures implying an enhanced inclusiveness of the redesign with regard to prior experience. The implications of these findings for the effectiveness of inclusive design for older users are discussed.

Keywords Inclusive design · Older adults · Prior experience · Competence · Usability · Ticket vending machines

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1 Introduction

Products meeting the ideals of inclusive design aim to minimise the number of people who have difficulty with or are excluded from use, or to control such exclusion by manipulation of product features [5, 23]. While previously the focus was on designing for users with highly reduced capabilities, the demographic change in most countries of the developed world makes it necessary to also look at the changing capabilities of older users within the normal range [10].

Prior experience is one of the main factors influencing the performance of older adults with technology. Products that better match the prior experience of their users increase the speed and effectiveness of interaction [3, 7, 10, 19, 20]. These findings suggest that in order to design successful and usable products, designers need to establish the level of prior experience in their respective target user groups. Unfortunately, the concept of technology experience is ill-defined and used inconsistently across studies [11, 32, 34]. Although a number of different definitions and operationalisations of experience exist (e.g. [11, 25, 32, 33, 36, 37]), the differing power of these operationalisations to predict the usability of products for older users has rarely been investigated systematically.

This study seeks to fill that gap in exploring the impact of different such operationalisations of experience on the usability of an interactive system. It is argued that technology experience, as it relates to inclusive design, has at least three components. It is proposed that two of these components, *exposure* and *competence*, are directly relevant for the current discussion about prior experience in inclusive design and that they can predict to different degrees the usability of a product for older users. In an empirical study these facets of expertise are each operationalised on three levels of specificity, their impact on usability is assessed, and implications for future research are drawn.

Of particular interest is the assessment of how the application of inclusive design principles to the redesign of a ticket machine will influence the impact of prior experience on usability. Inclusive design can only be successful if it can reduce the impact of prior experience on usability, because that means that technology can be usable independently from the prior knowledge of its users. This again is important in inclusive design for older adults, as, according to previous research, the differing experience of different generations with technology (e.g. with typewriters, TV remote controls, computer interfaces, or complex menu systems on mobile phones) can be challenging for everyone trying to design new technology [8].

2 Facets and measures of experience

The following sections analyse the concept of experience in more detail. They suggest distinguishing between different facets of experience helps to clarify the concept and its operationalisation in empirical studies.

2.1 Experience as exposure and competence

Experience with technology assumes different operationalisations in the literature [11, 25, 32]. From the multitude of operationalisations, three different components emerge: *exposure*, *competence*, and *subjective feeling*.

Exposure to technology can be split into at least three subcomponents: duration of use, intensity of use, and diversity of use. Duration of use describes the length of time a product has been used and can be measured as the number of months or years the product has been used. Intensity of use describes the frequency with which a product is used and can be measured in hours per week. Diversity of use describes the number of different functions used or tasks solved with the product. These three measures are not necessarily correlated. A person that has used a product for a long time (high duration) may have done so only sporadically (low intensity) while using only one specific function of the product (low diversity). Using only one measure of exposure could therefore considerably distort the outcome of a study on technology experience. Therefore, these measures of exposure are often combined and sometimes accompanied by other measures of exposure, including the *opportunity to use* the product or an indirect *measure of exposure to information* about the product [32].

The second component of experience, competence with technology, describes the level of skills and knowledge required for interacting with a product. Competence can be measured via self-assessment or objective tests. Examples of self-assessment include one-item statements (e.g. 'How well do you think you can handle the product?') or standardised multi-item questionnaires asking about different areas of user competences (e.g. self-efficacy with technology, [1]). Examples of objective tests include a simple test of typing skills (cf. [7]) or a knowledge test about terms and symbols commonly used in computer interfaces [29].

The third component of experience, subjective feeling, considers the actual user experience when using the product, that is, the users' private feelings and thoughts when interacting with technology [32, 33]. While all three components, exposure, competence, and subjective feeling can be looked at as preconditions or outcomes of interacting with technology (e.g. [32, 33, 36], exposure and competence are more often treated as preconditions, and subjective feeling is more often treated as a result of interacting with a product (cf. [28]). The focus here is on exposure and competence as preconditions for inclusive interaction.

How do exposure and competence relate to usability, that is, the effectiveness, efficiency, and satisfaction in use? Often, expertise is only operationalised in terms of exposure to technology, and a subsequent influence on usability is assumed. More likely, however, is that exposure influences usability via the build-up of skills and knowledge, that is, the competence of a user to interact successfully. Hence, it is expected that the influence of competence on usability should be direct and greater than the influence of exposure on usability (cf. [36]).

2.2 Levels of specificity

When considering prior experience, whether exposure or competence, it is important to determine the level of specificity on which prior experience with technology has the greatest impact on usability. At least three levels can be differentiated: prior exposure and competence (1) with the product in focus, (2) with other products of the same type, and (3) with a broad range of products of different types.

Exposure to the same product should impact usability the most. Users have gained skills and knowledge in operating the product, and they bring these to future uses of the product. On the next level of specificity, the experience with other products of the same type will also contribute to usability as certain operations (e.g. cut and paste in different software user interfaces) are ubiquitous across devices and the skills and knowledge gained can be transferred across products. Finally, exposure to, and competence in using technical devices on a more general level may impact usability to a lesser extent because the amount of transferable interaction knowledge may be lower.

3 Investigating the impact of exposure, competence, and specificity on usability

With a sample of older adults, the effects of the different facets of technology experience on the usability of ticket vending machines (TVM) were investigated.[1] The study had the following objectives:

First, to investigate separately the effects exposure and competence have on product usability: As discussed above, it is expected that the more direct effects of competence on usability are higher than the more indirect effects of exposure on usability.

Second, to disentangle the effects of different levels of specificity of technology experience: At the highest level of specificity the prior experience with the ticket vending machine is taken into account. As the TVM was operated via direct manipulation on a touch screen display and interaction was similar to interacting with a computer, at a level of medium specificity computer experience was measured. At the lowest level of specificity, experience with vending machines and electronic devices in general was measured. It is expected that the more specific the operationalisation of experience, the higher its impact on measures of usability.

Third, to investigate how the impact of prior experience on usability changes with a redesign of the original ticket vending machine following inclusive design principles: It is expected that a redesigned ticket vending machine will reduce the impact of relevant experience on usability.

Finally, a direct impact of the redesign on the usability of the ticket vending machine is also expected. A previous study by a different workgroup showed that the redesigned version enhances the usability of the TVM for older users [30]. Thus, it is expected that the redesigned version of the TVM will be more effective, more efficient, and more satisfying to use than the original version.

4 Method

4.1 Product simulations

Two versions of a German ticket vending machine (TVM) were used. They differed in appearance and menu structure but not in functionality.[2] The first version was a simulation of the original TVM of the Berlin public transport company BVG (and thus not our design). Its menu is structured largely along the lines of BVG's tariff system. The TVM's comparatively rigid navigation sequences often require interaction with buttons labelled with symbols that require computer experience to comprehend them. For example, in the navigation bar at the right of the screen, there are buttons labelled with an arrow, with the letter 'i' (referring to further information), or the letter 'C' (referring to the English words Cancel or Clear). Other computer-related features were arrow-buttons for scrolling through long lists of alternatives, an electronic shopping basket, and buttons labelled 'X' for removing items from the shopping basket (Fig. 1).

The second version (Fig. 2) was a redesign of the original ticket vending machine applying inclusive design principles that are intended to make the system more usable to different target groups. First, the redesigned TVM required less working memory capacity of the user. This is especially relevant in regard to inclusive design for the elderly, because cognitive capacities decrease with the age (e.g. [10, 27]). Second, the redesigned version reduced the need for familiarity with interaction principles and symbols frequently used in personal computer user interfaces. All buttons now had clear labels that contained words, not abbreviations or symbols. Third, the need for visual search was reduced by breaking down the task of purchasing a ticket into a number of manageable steps. This also eliminated the need of scrolling to access a specific menu option. Fourth, the user interface now represented the buying process in real life and the mental models of ticket buyers. The information that needs to be required to buy a ticket was now arranged in five tabs named *Who? Where*

[1] For comparisons between an older and a younger sample using the same ticket vending machines cf. [30].

[2] These ticket machines were also used by another workgroup before [30, 31], although in part with a different focus than the present study (i.e. investigating the effects of video instruction).

Fig. 1 Screenshots of the original version of the ticket vending machine. The *left panel* shows a screen for the selection of tickets for different tariff zones (short trip and zones *AB*, *BC*, *ABC*). The *right panel* shows the contents of the electronic shopping basket

Fig. 2 Screenshots of the redesigned ticket vending machine applying inclusive design principles. *Left*: At the beginning of the process, the ticket is incomplete, and the users start with selecting who (or what) is travelling (a regular adult, a child, a group, or a bicycle). *Right*: In the second step of the process, the users choose where they want to travel. They are assisted by a map of the larger Berlin area showing the different tariff zones *A*, *B*, and *C*

to? How long? How many? and *Pay* (cf. [30]). Fifth, the navigation and data modification were made flexible, because the tabs were constantly visible on the top of the screen and could be activated at all times to switch between different screens as needed. Sixth, visual metaphors are used to make functions and ticket information clear from a user's and task point of view. Central was an image of the final ticket to which information was added gradually with each relevant selection the user made. Information about the selected options was provided permanently using the ticket metaphor. The tariff system was visualised by showing a map indicating the different tariff zones. Triangular buttons pointing upwards and downwards were used for changing quantities, for example, the number of tickets to be purchased. Altogether, the graphical user interface and interaction are designed to be clear, simple, consistent, and flexible, in accordance with common principles and recommendations for inclusive design, especially for older users (see [4, 6, 13]). One design trade-off remained, however, reducing the cognitive load as well as the reliance on prior knowledge led to a design that requires a higher number of physical steps. This could have a negative effect on the efficiency of interacting with the redesigned version.

Both TVM versions were built in Squeak/Smalltalk and were used with a 20-inch touch screen monitor.

4.2 Participants and experience levels

Participants were recruited via leaflets, ads on the Internet, notice boards in adult education centres, and seniors' clubs as well as from databases of participants of previous research studies. Participants were selected via a prescreening that ensured a wide variety of experience with the BVG ticket vending machine and age. The aim was also to find equal numbers of male and female participants, although not successfully.

Altogether 60 participants were recruited to take part in the study. They were between 50 and 76 years old. This age range represents a single technology generation. According to Docampo Rama [8], people born between 1930 and 1960 belong to the 'electro-mechanical generation', as they grew up with, and should be most familiar with, electro-mechanical style user interfaces (e.g. the telephone, VCR, TV set).[3] Being members of the same technology generation made the participants comparable to each other regarding their experience with interactive products during their formative years (supposed to lie between 10 and 25 years of age).[4] On the one hand, this restricted the study to a younger–old cohort and left out the older–old. On the other hand, it was also not expected to find many people older than 80 years of age who use ticket vending machines and who were interested in this study.

Due to technical problems with writing the log file protocol, the data of two participants were incomplete (both were in the condition with the original TVM) and were excluded from further analysis. Of the remaining 58 participants, 34 were female and 24 male. Most participants used the ticket vending machine once a month or less (40 %) or never (24 %). About a third (36 %) even avoided the use of TVMs.

A between-subjects experimental design was used. There were 28 participants who interacted with the original version (19 female) and 30 who interacted with the redesigned version of the ticket machine (15 female). In allocating the participants to the TVM versions, effort was made to balance them according to age and prior experience with the BVG TVM. Descriptive statistics of age and facets of experience are shown in Table 1. Samples did not significantly differ regarding all prior experience measures.

Exposure (*Expo*) was measured at all three levels of specificity. At the most specific level (Expo-TVM), participants indicated which of a list of 18 different tickets they had already bought at BVG ticket machines (e.g. tickets for short trips, single tickets, group tickets, different forms of monthly tickets) and which of five different functions of the ticket machine they had already used (i.e. getting information, buying tickets, buying tickets for special events, topping up mobile phones and other). This resulted in a diversity measure that could theoretically range from 0 to 23.

At the level of medium specificity (Expo-Computer), participants indicated how often (from 0 = 'never' to 3 = 'frequently') they are engaged in eleven computer-related activities including word processing, picture editing, gaming, writing emails, online shopping, and online-banking. This resulted in a combined diversity × intensity measure that could theoretically range from 0 to 33.

Table 1 Participants' age and prior experience with technology

Variable	Original		Redesign		Comparison	
	Mean	SD	Mean	SD	T(df)	*P*
Age	61.96	7.79	61.50	7.43	0.23 (56)	0.817
Expo-TVM	4.39	2.99	5.44	3.95	1.12 (53)	0.269
Expo-Computer	11.68	7.10	13.47	5.62	1.07 (56)	0.291
Expo-Devices	22.14	4.68	23.77	4.40	1.36 (56)	0.179
Comp-TVM	3.73	1.45	3.73	1.76	0.01 (46)	0.994
Comp-Computer	19.39	7.86	18.53	6.28	0.46 (55)	0.650
Comp-Devices	33.14	9.72	35.57	7.40	1.07 (56)	0.288

Expo exposure, *Comp* competence

Comparison between samples using the original and redesigned TVM

At a low specificity level (Expo-Devices), participants indicated their usage (from 0 = 'do not know this device' to 4 = 'use frequently') of each of thirteen devices from ATMs and vending machines to information systems and gaming machines. This resulted in a combined diversity × intensity measure that could theoretically range from 0 to 52.

Competence (*Comp*) was also measured at all three levels of specificity. At the most specific level (Comp-TVM) participants indicated their competence on the item: 'How well do you think you can handle the BVG ticket vending machine?' (1 = '−−− very badly' to 7 = '+++ very well').

At the level of medium specificity (Comp-Computer) participants completed a standardised test of computer literacy for older adults [29] with a score that could theoretically range from 0 to 30.

At a low specificity level (Comp-Devices), participants filled in a standardised questionnaire about their self-efficacy with interactive technology [1] with a score that could theoretically range from 12 to 60.

4.3 Procedure and measurement of dependant variables

The study took place in a laboratory at the Technische Universität Berlin. After giving their informed consent about the study, participants filled in a set of questionnaires asking them about their familiarity with the tariff system of the BVG and their experience with the BVG TVM. Participants were then assigned to the original or the redesigned version of the ticket machine. Participants using the original version of the TVM did not differ significantly in their age and experience from participants using the redesigned version of the TVM (Table 1).

In 12 tasks participants purchased preselected tickets from the machine. Each task was presented on a different

[3] The electro-mechanical generation follows the 'mechanical generation' born before 1930 and precedes the 'software generation' born after 1960.

[4] Thus, membership in a technology generation is an exposure measure of low product specificity that refers to experiences made in a life period in which people are highly receptive to new technology. The fact that the participants of this study are members of the same technology generation, however, does not mean that they are necessarily homogenous with respect to more recent experience with computers (e.g. due to different exposure to computers for those still working versus those already retired).

sheet of paper. Examples include (1) 'Please buy a single ticket, regular fare, Berlin zones AB'; (7) 'You are travelling with friends and you need two group tickets, Berlin zones ABC. Please buy these tickets in one go'; (10) 'Please buy a ticket covering the month of May and fare zones B and C. You think it is alright to leave after 10 am'.

During their interaction with the system, participants' faces and actions on the touch screen were video-recorded. Participants received help only when they were stuck and explicitly asked for help.

After solving the block of tasks participants' filled in another set of questionnaires, asking for their evaluation of the system as well as their experience with computers and a wider range of devices. An interview and debriefing followed. The whole session lasted about 90 min on average, of which about 25 min were spent interacting with the TVM.

Usability was measured according to ISO 9241-11 [17] as the effectiveness, efficiency, and satisfaction of use. Effectiveness was measured as the percentage of correctly solved tasks. If, for example, 8 of the 12 tasks were correctly solved, the score was 75 %. A task was solved when the correct types and amounts of tickets were selected and the user proceeded to buy them.[5]

Efficiency was measured as the average times and steps of correctly solved tasks. First, standardised z-values [9] were calculated for each task (across the whole sample). This was done because the tasks had different amounts of baseline steps and times, and averages would have been biased by the number and distributions of tasks not correctly solved.

Satisfaction was measured in terms of the subjective consequences of intuitive use (questionnaire QUESI with scores between 1 and 5, [16]) and of the seven dialogue principles specified in the ISO standard 9241-110 ([18]; questionnaire ISO 9241/110-S with scores between 1 and 7, [24, 26]).

5 Results

This study set out to investigate the impact of different facets of prior experience on usability measures. Thus, a number of multivariate regressions for different levels of exposure and specificity of experience were solved. The higher the beta weights for the predictors in these regressions, the greater the impact of that facet of experience on usability. Thus, these analyses help to identify facets of experience that exert the highest influence on usability measures.

An additional aim was to see whether redesigning the TVM diminishes the impact of these facets of experience on usability. Thus, the explained variance and beta weights of the multiple regressions of both versions of the TVM are compared. If the explained variance and beta weights tend to be smaller in the redesigned version, then the impact of prior experience on usability could be lowered by the design. Finally, a direct comparison of the absolute usability measures of the two versions is reported.

The results are discussed in the following order. First, the differential effects of exposure and competence on the usability of both versions of the ticket vending machine are reported. Second, the original and redesigned versions of the ticket vending machine are compared in their effectiveness, efficiency, and satisfaction of use.

5.1 Effects of experience on usability

These analyses revealed which of the components of experience and what levels of specificity contributed the most to predicting the usability of the systems. Because the measures of experience were significantly intercorrelated, multiple regression was used to assess the unique contributions of the different facets of technology experience to predict levels of usability.

The analyses were made for the overall sample as well as for the subsamples using the original and redesigned ticket vending machines. Thus, the influence of the redesign on the relation between experience and usability can be assessed.

As the relatively small sample sizes only allowed for a small number of predictors entered into each regression model to yield meaningful results (cf. [9, 35]), analyses proceeded in a step-by-step approach. First, the effects of exposure and competence on usability are investigated separately. Then, the strongest predictors of these analyses are entered into a third analysis determining the combined effect of exposure and competence on usability measures. Preliminary analyses were conducted to check for violations of the assumptions of normality, linearity, and multicollinearity [9, 35].

5.1.1 Effects of exposure on usability

Exposure to technology, on different levels of specificity, explained, averaged across the different usability measures, 13 % of the variance in the overall sample (R^2, Table 2). In the overall sample, prior exposure to technology had the highest impact on efficiency/time, some impact on effectiveness but less on efficiency/steps and satisfaction

[5] Note that although in practice combinations of several tickets could also be bought in several subsequent buying processes, tasks involving the purchase of a combination of tickets were only regarded as correctly solved when all required tickets were bought during a single process. This strict rule could have artificially lowered effectiveness measures.

measures. Significant effects (β weights) were only found at the medium level of technology specificity: exposure to computers.

The redesigned version of the TVM was different from the original version. Averaged across all usability measures exposure variables explained more variance in the original version (30 %) than in the redesigned version (12 %). In the original version, all significant beta weights were for exposure to computers, while in the redesigned version only one beta-weight achieved marginal significance (also for exposure to computers).

5.1.2 *Effects of competence on usability*

Competence with technology, on different levels of specificity, explained, averaged across the different usability measures, 22 % of the variance in the overall sample (R^2, Table 3). Competence with technology had the highest impact on efficiency/time, effectiveness, and satisfaction measures. Significant effects (β weights) were found at the highest and medium level of technology specificity: prior competence with the ticket machine and with computers. On average, the effects of competence on usability (Table 3) were numerically higher than the effects of exposure on usability measures (Table 2).

Also, in the redesigned version of the TVM, competence with technology explained less variance than in the original version (Table 3). Averaged across all usability measures, the explained variance was higher for the original version (48 %) than for the redesigned version (16 %). Also, the number of significant beta weights is lower, and the absolute values of beta weights are to a large part lower in the redesigned version.

5.1.3 *Joined effects on usability*

To assess the combined effect of exposure and competence on usability, the strongest predictors from the previous two analyses were joined in the regression models (Table 4). The percentage of explained variance did not increase compared to the analysis including competence measures only (Table 3). Also, the most influential predictors are measures of competence while the only exposure variable contributed much less to usability (except for its marginally significant effects on efficiency/time). Again, in the redesigned version of the TVM, less variance was explained by the experience variables than in the original version. Averaged across all usability measures, the explained variance was higher for the original version (47 %) than for the redesigned version (15 %).

5.2 Effects of inclusive design on usability

The objective of the last analyses was to determine whether the redesign of the original ticket vending machine had any direct effect on usability measures, that is, the effectiveness, efficiency, and satisfaction in use. The comparison between the two TVM versions is shown in Table 5.

Table 2 Effects of exposure on usability

	Effectiveness	Efficiency		Satisfaction		Averages
	%solved	Time	Steps	QUESI	ISO	
Overall sample						
R^2	0.16*	0.32***	0.02	0.09	0.05	0.13
$\beta_{Expo\text{-}TVM}$	−0.10	−0.12	−0.03	0.16	0.09	
$\beta_{Expo\text{-}Computer}$	*0.45***	*−0.50****	−0.15	0.11	0.20	
$\beta_{Expo\text{-}Devices}$	−0.08	−0.02	0.09	0.13	0.03	
Original TVM						
R^2	0.24^m	0.42**	0.30*	0.22	0.32*	0.30
$\beta_{Expo\text{-}TVM}$	−0.07	−0.09	−0.01	0.23	−0.10	
$\beta_{Expo\text{-}Computer}$	*0.52**	*−0.56***	*−0.44**	0.25	*0.53***	
$\beta_{Expo\text{-}Devices}$	−0.10	−0.12	−0.22	. 13	0.18	
Redesigned TVM						
R^2	0.08	*0.32**	0.09	0.04	0.07	0.12
$\beta_{Expo\text{-}TVM}$	−0.08	−0.23	−0.25	0.19	0.22	
$\beta_{Expo\text{-}Computer}$	0.33	*−0.43^m*	−0.10	−0.14	−0.29	
$\beta_{Expo\text{-}Devices}$	−0.06	−0.03	0.10	0.13	0.03	

Multiple regression results show standardised β coefficients

Cells with significant β values are shown in italics, *** $p < .001$, ** $p < .01$, * $p < .05$, ^{m} $p < .10$

Table 3 Effects of competence on usability

	Effectiveness	Efficiency		Satisfaction		Averages
	%solved	Time	Steps	QUESI	ISO	
Overall sample						
R^2	0.27**	0.35***	0.09	0.25**	0.15^m	0.22
$\beta_{Comp\text{-}TVM}$	−0.09	*−0.13*	−0.01	*0.33**	0.22	
$\beta_{Comp\text{-}Computer}$	*0.41***	*−0.48***	*−0.33**	0.17	0.20	
$\beta_{Comp\text{-}Devices}$	0.19	−0.15	0.11	0.23	0.16	
Original TVM						
R^2	0.34^m	0.50**	0.40*	0.49**	0.68***	0.48
$\beta_{Comp\text{-}TVM}$	−0.02	−0.20	−0.18	*0.39**	*0.45***	
$\beta_{Comp\text{-}Computer}$	*0.42^m*	*−0.60***	*−0.54**	*0.51**	*0.67***	
$\beta_{Comp\text{-}Devices}$	0.25	−0.14	−0.12	0.15	0.07	
Redesigned TVM						
R^2	0.20	0.21	0.02	0.22	0.14	0.16
$\beta_{Comp\text{-}TVM}$	−0.14	−0.14	−0.06	*0.42**	0.24	
$\beta_{Comp\text{-}Computer}$	*0.42^m*	−0.28	−0.10	−0.25	−0.38	
$\beta_{Comp\text{-}Devices}$	0.11	−0.21	0.04	0.29	0.24	

Multiple regression results show standardised β coefficients

Cells with significant β values are shown in italics, *** $p < .001$, ** $p < .01$, * $p < .05$, ^{m} $p < .10$

Table 4 Effects of the strongest exposure and competence measures on usability

	Effectiveness	Efficiency		Satisfaction		Averages
	%solved	Time	Steps	QUESI	ISO	
Overall sample						
R^2	0.24**	0.37***	0.10	0.21*	0.13	0.21
$\beta_{Comp\text{-}TVM}$	−0.10	−0.13	−0.02	*0.31**	0.21	
$\beta_{Comp\text{-}Computer}$	*0.48**	−0.31	*−0.43^m*	0.31	0.27	
$\beta_{Expo\text{-}Computer}$	0.03	*−0.31^m*	0.20	−0.05	−0.01	
Original TVM						
R^2	0.30	0.50**	0.39*	0.49**	0.67***	0.47
$\beta_{Comp\text{-}TVM}$	−0.02	−0.21	−0.18	*0.38**	*0.45***	
$\beta_{Comp\text{-}Computer}$	0.47	−0.46	−0.55	*0.78**	*0.72***	
$\beta_{Expo\text{-}Computer}$	0.08	−0.26	−0.06	−0.25	−0.01	
Redesigned TVM						
R^2	0.19	0.29^m	0.04	0.15	0.09	0.15
$\beta_{Comp\text{-}TVM}$	−0.15	−0.12	−0.06	*0.41^m*	0.23	
$\beta_{Comp\text{-}Computer}$	*0.50^m*	−0.03	0.07	−0.14	−0.24	
$\beta_{Expo\text{-}Computer}$	−0.05	*−0.48^m*	−0.22	0.01	−0.06	

Multiple regression results show standardised β coefficients

Cells with significant β values are shown in italics, *** $p < .001$, ** $p < .01$, * $p < .05$, ^{m} $p < .10$

Contrary to the original expectations, there were no statistically significant differences between the two versions of the ticket vending machine regarding the effectiveness, efficiency (time), and satisfaction in using them. Both versions only differed with respect to the number of steps taken. The original ticket vending machine required fewer steps than the redesigned version, thus being more efficient to use with regard to steps. This, however, was expected, given the trade-offs in design between mental workload and physical steps (see above).

Table 5 Comparison of the original and redesigned ticket vending machines regarding their effectiveness, efficiency, and satisfaction in use

	Original		Redesign		Comparison	
	Mean	SD	Mean	SD	T(56)	*p*
Effectiveness						
%solved	76.54	18.93	77.10	17.49	0.12	.908
Efficiency						
Time (z-scores)	−0.01	0.76	0.16	0.55	0.99	.327
Steps (z-scores)	−0.39	0.36	0.39	0.36	8.27	.000
Satisfaction						
QUESI	2.86	0.84	2.85	0.68	0.04	.965
ISO	4.61	1.29	4.31	1.14	0.92	.360

6 Discussion

The main objective of the paper was to disentangle different views on the concept of prior experience and to investigate its contribution to usability. The first expectation was that the two components of experience, namely exposure and competence, predict usability to different degrees. It was expected that the effects of competence on usability are higher than the effects of exposure on usability because of the more direct links between competence and interaction behaviour. This hypothesis is supported by the data. In terms of the explained variance (R^2) and the beta weights of single measures, competence measures were related more strongly to usability than were exposure measures. There seems to be a differential effect too: competence measures seem to better predict satisfaction outcomes, and exposure measures seem to better predict effectiveness outcomes. However, in a combined analysis, this difference vanishes, as competence measures tended also to be stronger for effectiveness outcomes (Table 4).

Second, it was expected that the more specific the operationalisation of experience, the higher its impact on measures of usability. This hypothesis is partly supported by the data. The lowest level of specificity (experience with a broad range of devices) does have no significant effect on usability measures. The medium and higher levels of specificity are more important. It even seems that the medium level of experience (with devices of the same kind) is more closely related to usability than the level of high specificity (experience with the same device). Whether these results represent an artefact that is dependent on the specific prototypes and measures used in this study is not quite clear. Work on the general concept of 'technology familiarity' (e.g. [2]), basically a diversity × intensity exposure measure, shows that also measures of relative low specificity can be useful in the prediction of usability. These contradicting results point out that the impact of different levels of specificity needs to be studied further employing a range of different devices. The possibility remains, however, that measures of high specificity are less useful in predicting usability. Experience with a range of similar devices may determine usability measures more than device-specific knowledge. In the former case, the mind can apply more abstract and consistent knowledge that has been more frequently practised than in the latter case. To know the general meaning of *scrolling* or of *buttons labelled 'C'* might be more useful than having experienced these on only one device. This broad-level knowledge, however, should be less useful for devices with very idiosyncratic user interfaces. Here, one would assume that experience of the same device would have more impact than experience with devices of the same type.

Third, it was expected that, for the redesigned ticket vending machine, experience measures would have a reduced impact on usability. This hypothesis is clearly supported by the data. The influence of prior experience, be it exposure or competence, on usability was greatly reduced in the redesigned version of the TVM. Usability variables did to a much lesser extent depend on the prior knowledge of the participants of the redesigned version. This suggests that inclusive design principles can have an impact by reducing the dependency of usability on prior experience variables. Thus, these findings show some not-so-obvious effects of inclusive design and thereby the power of applying well-chosen principles for inclusive interaction to counter the need for prior experience.

Fourth, it was expected that redesigning the original ticket vending machine according to inclusive design principles enhances usability. The data, however, show no such a direct effect of the redesign on usability variables. This effect cannot be explained by differences between participants in the experimental groups regarding their prior experience (Table 1). The result seems peculiar, as prior research conducted by a different research group using the same TVM prototypes revealed that the redesigned version was more usable than the original version [30]. Compared to these previous results, however, the general level of usability was higher in the present study and especially the original version achieved higher results, thus eliminating the difference between both versions. Looking at the characteristics of the older participants in both studies, the differences in results can also be explained by differences in prior experience with the original TVM. In the Sengpiel [30] study, fewer participants used the TVM more than 12 times a year, and more participants never used the TVM than in the current study. In the Sengpiel study, there were also a higher number of people avoiding the use of TVM altogether in their daily lives. These differences in participant samples offer the conclusion that, for people with low TVM experience (as in the previous study), the redesigned version provided a gain in usability when compared with the original version. In the current study, more highly experienced TVM users participated, so that the original version appeared to be quite usable already, and no further gain in usability could be achieved when using the redesigned version.[6]

This discussion entails the question of how much difference in experience there needs to be in order to obtain a practically significant effect of experience on usability. Looking at the non-standardised regression coefficients of the joined effects of competence and exposure on usability, one finds that for the original version a difference in rating the competence with the ticket vending machine by 2.5 on the 7-point scale would reduce satisfaction measures by 1 point (ISONORM) or 0.5 points (QUESI). It would change the z-score of time by 0.25, the z-score of steps by 0.11. Similarly, a change in computer literacy by 5 on the 30-point scale would reduce satisfaction measures by about 0.5 each. It would also change the z-score of time by 0.25 and the z-score of steps by 0.13. This is to show that for the original version, different levels of experience can have practically significant effects, while for the redesigned version, due to the lack of significant regression results, it is likely that any variation in user experience does not affect usability at all.

7 Limitations and suggestions for further work

Encouraging as these results seem some possible limitations of the study need to be considered. First, the analysis may not seem to be complete because some of the experience variables are (negatively) correlated with *age* and age should therefore be included in the regression models. However, including age in the above regression analyses does not change the results, that is, age has no additional value in predicting usability. The only exception is the contribution of age to efficiency/time that amounts to 5–7 % changes in the explained variance of the overall sample, compared to the same regression models without age as a predictor. This finding can be seen as a replication of earlier studies on the effect of age on the speed of interaction [3, 10, 20]. Furthermore, in the subsamples, the age effect is much higher for the original TVM (7–17 % changes of the explained variance) than in the redesigned TVM (3–5 % changes), indicating again that the redesign was more inclusive with regard to age.

Repeating the original analyses with *sex* as an additional variable has, in most cases, failed to show significant effects for sex. The only exceptions occurred in the subsample of the original TVM for satisfaction measures. Here, the changes in explained variance were quite large (10–19 %), indicating that men were more likely to be satisfied. These effects could not be found for the redesigned TVM or the overall sample. Moreover, there were no effects of sex on performance variables.

Further influencing variables like cognitive ability, self-efficacy in using technology, computer anxiety, etc., may also have an impact on the results, and their effects should be investigated in further studies. In that case, larger sample sizes than employed in this study will be required to obtain meaningful results (cf. [35]).

Second, as the results were obtained from using ticket vending machines, it is not clear how far these results can be generalised to a larger range of interactive products. Previous research has shown that the effects of age and prior experience on interaction performance can vary according to the type of product [19, 20, 22]. Clearly, replications of the findings of this present study, including products from other domains, are needed.

Third, on a more speculative note, other measures of experience may be interesting to explore. The model presented in this paper assumed that repeated exposure leads to competence. Competence is often measured as a type of declarative knowledge that is accessible to consciousness. It would, however, also be interesting to explore the more subconscious route to tacit knowledge that cannot be easily verbalised. Research in information systems uses experience-related concepts such as familiarity [12] or habit [21] that are operationalising more automated knowledge. It would be interesting to see how these constructs relate to usability or, more specifically, intuitive use (cf. [14]).

8 Conclusion

This study proposes a step forward to acknowledging the different facets of prior experience of older adults in using technology and the effects of these facets on product usability. It is proposed that prior experience has at least three components that require separate consideration: exposure to technology, competence with technology, and subjective feeling. Exposure and competence were measured at different levels of specificity, and their combined effect on usability was investigated.

The results have several practical implications. First, competence measures had a higher impact on usability than exposure measures. Thus, for example, if one wishes to account for the effects of prior experience on the results of a usability test, one is best advised to prefer competence

[6] There could even be negative transfer of the knowledge about the original TVM to the redesigned version, thus reducing the usability of that version. Given the generally increased level of usability, however, we find this possibility not very likely.

measures to measures of exposure. Using measures of exposure, one could underestimate the impact of prior experience with technology. The difficulty, however, is to find appropriate measures. Exposure measures are comparatively easy to obtain. Competence measures are often subjective (measuring self-ascribed competence). More objective competence tests may be highly device or population specific. For example, the computer literacy test employed in this study is restricted to the range of interaction elements to be found in current computer software and is only useful for testing the competence of older adults, because the test would not be able to differentiate well between younger users (who are almost all computer literate). This, however, may change in the future, as research progresses and more generic competence measures will be available.

Second, it may be profitable to not only employ one measure of experience, but also several measures on different levels of specificity. The results of this study suggest that experience with the same device and similar devices of the same kind are important, but even broader measures that measure experience with a large range of devices may be of utility.

Finally, this study has shown that inclusive design can reduce the impact of prior experience on usability, even when no overall change in usability measures can be detected between the original and the redesigned version of a product. Evaluators are therefore encouraged not only to look at the absolute numbers of their outcome measures but also to explore the relationships between experience and usability, employing, for example, multiple regression techniques. This is especially important in inclusive design where the objective is to decouple usability from specific user capabilities. These findings open up new ways of looking at the impact of inclusive design principles and of different facets of prior experience on usability. Further research should try and corroborate these findings in different domains of product interaction.

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