AID-Watch: Increasing Time Processing Ability in Adolescents With Cognitive Impairments

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Abstract. People with cognitive impairments are frequently affected in their time-processing ability. This lack of timely orientation makes them dependent on others to manage their time allocation to tasks throughout the day. To enable affected adolescents in understanding daily schedules as well as recognising and attending appointments and routines more independently, we developed a digital watch face that highlights activity-symbols instead of numbers. A four-day ABAB test with six adolescents in an assisted living facility revealed that participants showed significant improvements in time orientation and time management when using the watch. The young users rated the user experience as "excellent", confirmed by newly acquired skills, expected learning effects, and enjoyment during use. Care personnel, as secondary users, reported a reduction in stress, which facilitated improved time management and enhanced the quality of care provided. In future work, we strive to extend our research by long-term examinations to understand learning effects and quantitative effects on independence and autonomy.

Keywords: time-processing ability, intellectual disability, accessibility, cognitive impairments, assisitive technology, cognitive assistance device, time aid, inclusive design, augmentative and alternative communication

1 Introduction

Time management is fundamental to everyday life, essential for public transport schedules, work meetings, and personal appointments. Difficulties understanding time can significantly complicate daily activities, particularly for individuals with cognitive impairments who struggle to read the clock and manage time effectively. This characteristic can be described as decreased time-processing ability (TPA), a concept that is split in three subcategories defined by the WHO's International Classification of Functioning, Disability and Health [17]. **Time orientation (TO)** describes the awareness of the day and the understanding of one's relative position in time. **Time management (TM)** refers to the mental function of arranging events and activities in a temporal sequence and allocating time periods to them. **Time perception (TP)** pertains to the subjective experience of time duration and passage. Individuals with cognitive impairments, such as those with intellectual or developmental disabilities e.g. autism or attention deficit hyperactivity disorder (ADHD), are particularly affected by decreased TPA [1, 9, 11]. However, symptoms (TPA) should be prioritised over diagnoses because TPA can vary significantly among individuals with the same diagnosis [9] and may be experienced by groups outside these diagnosis, such as children [9], older adults, and individuals with certain neurological conditions e.g. dementia [6]. Aspects of TPA are associated with the extent to which an individual is able to live independently and autonomously [13]. With decreased TPA, individuals may become highly reliant on caregivers and exhibit passive participation in everyday activities, also imposing substantial stress on caregivers [3]. To counteract these effects and enhance independence, cognitive assistance devices / time aids are developed and explored. For example, *Quarter Hour Watch*, *Handi* and *Time Rule*, all of which visualise time with LED light dots that provide a visual countdown and sound when time is up [2, 16]. *Handi* also provides a daily schedule overview with text and symbols, supported by a synthetic voice for additional information [16]. Furthermore, analogue weekly planners display days in colour-coded columns, allowing symbol-based activities to be visualised and scheduled like a timetable [16]. These devices, aimed at improving TPA, have been studied for decades but have always been limited to the technical possibilities of the time, thus were limited in mobility, adaptability, and scalability. Common issues with existing aids include limited personalisation, negative user and peer perceptions, and insufficient support [2, 16]. For this reason, we envisioned and prototyped the smartwatch concept AID-Watch [14]. It enables users to wear their daily schedules on their wrists in an interactive and user-friendly manner, specifically designed to meet the needs of individuals with cognitive impairments while minimising stigma by resembling a common smartwatch. Time and daily schedules are displayed in an accessible format (see Fig. 1) including a visual daily schedule through sectors and symbols (TO), an indication of the current event that is announced at the start with vibration and voice output (TM), and a progress indicator showing the remaining duration of activities (TP). This visual language makes the abstract concept of time experiential in its dynamic nature. AID-Watch

Fig. 1. The developed AID-Watch watch face on a Samsung Galaxy Watch 4, METACOM Symbols © Annette Kitzinger.

therefore addresses all three subcategories of TPA and was iteratively developed using a user-centred design process with a potential user, following the principle *solve for one, extend to many* [12]. Initial testing aimed to ensure that the design meets the needs of people with cognitive impairments [14]. The aim of this paper is to *extend to many* by validating the research product in an assisted living facility with more diverse individuals experiencing decreased TPA. The primary objective is to enhance TPA, with the potential to increase independence and autonomy in daily living. Additionally, the study will evaluate the user experience (UX) to validate that AID-Watch is highly user-friendly. Based on qualitative data from our previous study we assume that:

H1 When using AID-Watch time orientation increases in participants.
H2 When using AID-Watch time management increases in participants.
H3 When using AID-Watch time perception increases in participants.
H4 AID-Watch provides participants with a positive UX.

2 Method

To summatively evaluate the effects of AID-Watch on individuals' TPA, we observed adolescents with cognitive impairments who wore AID-Watch (see Fig. 1) displaying their individual daily schedules.

2.1 Study Design

The within-study followed an ABAB-reversal design across four evaluation days to adjust for learning and exposure effects. On the two A days, participants followed their regular daily routines without AID-Watch (baseline). In the B condition, they also followed their daily routines but were assisted by AID-Watch (intervention). We redundantly operationalised all hypothesis, measuring participants' TPA through researcher measurements and care personnel assessments, and UX through participants' self report and care personnel assessments. The TPA researcher measurements used quantifiable questions as well as objective observations to quantify effects on TO, TM, and TP:

The participant's TO was measured by their ability to name events of the day, recall already passed events, and identify the current and upcoming event (in % of correctly named events). The participants' TM was measured by their ability to attend events more punctual (in minutes late/early, TM), without reminders from care personnel. To prevent participants from missing appointments, we set the maximum possible deviation to ten minutes. If this limit was exceeded, the participants were notified again. The participants' TP was measured by their ability to identify if the current event is still ongoing and to identify if the remaining time is short ($< 20\%$ of time remaining) or long ($> 20\%$ of time remaining).

TPA questionnaires for care personnel assessment comprised ten items, each rated on a 7-point Likert scale ranging from "-3 - strongly disagree" to "3 -

strongly agree". The validated TPA measurement method "KaTid®" is not available in German [8]. To obtain a standardized assessment for all three TPA dimensions, we developed our own TPA questionnaire. Items are inspired from the "KaTid®" [8] as well as WHO classifications [17] and adapted to reflect day-specific everyday scenarios of the participants (see Appendix A, available at https://github.com/haukewendt/CWUAAT).

Measurements of UX comprised participants' self-reported UX using an "easy read" version of the UEQ-S specifically designed for individuals with cognitive impairments, which utilises smiley scales instead of traditional Likert scales [5]. For care personnel assessment the standard UEQ-S was used as proxy ratings for the participants [15]. UEQ-S ratings allow for the comparison to percentiles in a benchmark system based on over 9000 ratings of 246 products [7]. Ethical clearance for this study was obtained from the local university's review board.

2.2 Participants

Seven adolescents living in a facility for assisted living combined with a school for special needs participated in our study. Our inclusion criteria required participants to have issues in at least one of the three subcategories of TPA and no prior experience with AID-Watch. Participants were suggested by caregivers based on symptoms rather than specific impairments or diagnoses. After conversations with multiple living groups, we selected two groups with the organisational advantage of multiple participants in the group and with schedules that were easy to keep consistent over the study period. We also spoke with the participants to confirm their fit and feasibility for participation. The participants had different diagnoses, including epilepsy, cerebral palsy or spina bifida, but all of them had either an intellectual or developmental disability. We obtained written consent for participation from the parents or legal guardians of the participants, and secured ongoing verbal consent from the participants on each study day. Participants were offered 34 Euro as compensation. One participant was excluded from the data collection after the first two study days because their consent was no longer given. The care personnel prepared us for this possibility and suggested recruiting a backup-participant before the study started. This approach allowed us to proceed with six participants for the second baseline and intervention days. The data from the initial participant was excluded from the dataset. However, we included the data from the new participant in our results to avoid further reducing the sample size. The final six participants (3 male, 3 female) whose data was analysed were aged between 12 and 17 years ($M = 15.67$, $SD = 2.50$).

2.3 Procedure

For the interface, we used a Samsung Galaxy Watch 4 (44 mm) due to its comparatively large display. Our WearOS application displayed the watch face and offered auditory reminders via speech output. We used each participants' individual daily schedule to create matching digital schedules on AID-Watch (see Fig. 1). The application was synchronised with Google Calendar, where participants' schedules were managed. Due to the size constraints of the watch and insights from prior research, we opted to display only activities and events lasting longer than 45 minutes [14]. For each event sector we assigned one icon of the METACOM symbols [10], which are a widespread standard in German care facilities and familiar to participants and caregivers.

In preparation for the study, care personnel filled in a TPA pre-survey and a Functional Activities Questionnaire [4] for each participant as a control variable for the study's evaluation. All four evaluation days were scheduled on the same weekday in four consecutive weeks to ensure comparable schedules. Data collection started at noon after obtaining renewed verbal consent from each participant and an initial explanation of the procedure. We then accompanied the participants for the remainder of the day until their bedtime. On intervention days, we additionally equipped participants with AID-Watch and provided a brief explanation of its functionality and operation. The watch display was set to always-on mode. At the start of each event, participants received a visual and vibrotactile reminder in combination with speech output that announced the event's name and time. Throughout the day, we documented key observations and interactions with the device. The TPA researcher measurements comprised two measurement points per TPA-subcategory per day. These points in time were defined based on the individual's schedule, where the activity matched the task e.g. TM to measure punctuality for dinner. They remained the same across treatment and intervention days.

On days with AID-Watch, we asked participants to fill in the "easy read" UEQ-S before bedtime. After removing the watch, the participant's caregiver completed the TPA questionnaire (baseline and intervention days) and the standard UEQ-S (intervention days only). After the four evaluation days, we conducted a separate semi-structured interview with care personnel to obtain a final assessment of their experience, observations and opinions on the use of AID-Watch. Due to space restrictions, qualitative data on interaction behaviour and care personnel remarks will be reported elsewhere.

3 Results

Two measurements per participant per day result in a total of 44 data points for each TPA subcategory (instead of 48, because the backup participant only participated on the second baseline and intervention day). Not all of them could be collected or used. Exemplary reasons were participants falling asleep, receiving hygiene measures, or being reminded about an event by someone else. Therefore, some of the following results are missing single data points.

Our control variables, the pre-surveys on TPA and Functional Activities are in line with the following findings.

3.1 Time orientation (TO)

When asked to name upcoming and already passed events of the day, participants named significantly more events correctly on days with AID-Watch ($M =$

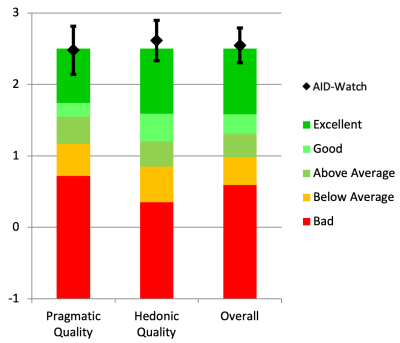

Fig. 2. Combined mean UEQ-S scores of participant and caregiver ratings for AID-Watch in comparison to benchmark ratings of over 200 products' UX [7], place it in the top 10%, indicating an "excellent" UX.

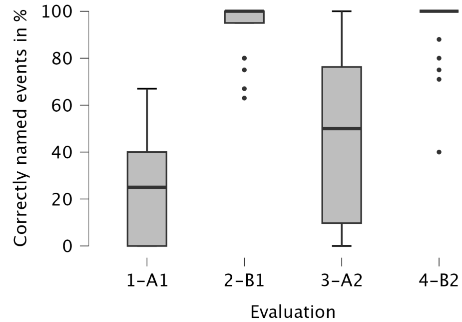

Fig. 3. Correctly named events (upcoming / passed, TO) raw data ($n = 87$), outlining Mdn and IQR. Whiskers represent range of data, excluding individually plotted outliers.

$91,9\%, SD = 7,5\%$) than on days without AID-Watch ($M = 37,6\%, SD = 15,7\%$), $t(5) = 9.27$, $p < .001$, $d = 3.78$. When asked to name the current and upcoming events, participants correctly identified an average of 100.0% (43/43) with AID-Watch and 84.1% (37/44) without AID-Watch. Therefore, "false" answers could be eliminated, with a significant improvement (χ^2 (1, $n = 87$) $= 7.44$, $p = .006$, $Cramer's\,V = 0.29$). Caregiver ratings of TO show a significant improvement ($t(5) = 5.72$, $p = .001$, $d = 2.34$) when comparing days with AID-Watch ($M = 2.37$, $SD = 0.47$) and days without AID-Watch ($M = -0.57$, $SD = 1.59$).

3.2 Time management (TM)

Participants were reminded by the researchers twice each evaluation day to show up at certain events on time. After these reminders, no further reminders from the care personnel were allowed. Reminders were given on average 24 min ($n = 22$, $SD = 10.84$) before an event on baseline days and 22 min ($n = 21$, $SD = 9.47$) on intervention days. Participants were significantly more punctual with AID-Watch (average deviation 3 min, $SD = 2.99$) than without AID-Watch (average deviation 7 min, $SD = 3.28$), $t(5) = 3.53$, $p = .008$, $d = 1.44$. Caregiver ratings of TM show a significant improvement in a paired samples t-test ($t(5) = 5.54$, $p = .001$, $d = 2.26$) when comparing ratings for days with AID-Watch ($n = 6$, $M = 1.96$, $SD = 0.83$) and days without AID-Watch ($n = 6$, $M = -1.67$, $SD = 1.46$). The maximum possible deviation of 10 min was reached six times with AID-Watch and twelve times without AID-Watch.

3.3 Time perception (TP)

When asked to answer whether the current event is still ongoing, participants answered correctly 100.0% (20/20) with AID-Watch and 90.0% (18/20) without AID-Watch. Therefore, "false" answers could be eliminated, but no significant improvement was determined by the chi-square test (χ^2 (1, n = 40) = 2.11, $p = .147$, $Cramer's\,V = 0.23$). When asked to answer whether the current event is short or long, participants correctly answered an average of 66.7% (8/12) with AID-Watch and 66.7% (8/12) without AID-Watch and consequently no improvement was measured. Caregiver ratings of TP show a significant improvement in a paired samples t-test ($t(5) = 2.99$, $p = .015$, $d = 1.22$) when comparing ratings for days with AID-Watch ($M = 0.89$, $SD = 1.67$) and days without AID-Watch ($M = -1.44$, $SD = 1.70$).

3.4 User Experience (UX)

Participants using AID-Watch reported an average UEQ-S score of 2.34 (n = 11, SD = 0.74), while caregivers reported an average score of 2.75 (n = 11, SD = 0.27) for UX observed in participants. Both correspond to "excellent" UX, ranking in the highest 10% of the UEQ-S benchmark (see Fig. 2). This results in an overall score of 2.55 ($n = 22$, $SD = 0.58$) as well as subscale scores of 2.48 ($n = 22$, $SD = 0.81$) for pragmatic quality and 2.61 ($n = 22$, $SD = 0.67$) for hedonic quality.

4 Discussion

The scope of this research was to understand and measure the effects of AID-Watch on TPA in adolescents with cognitive impairments. The results show that AID-Watch can significantly increase TPA. Our two-fold approach combined quantitative measurements through researchers and self-report, as well as the assessment by care personnel. Both TO and TM show large effects in both dimensions, see H1 and H2 confirmed by our data. However, our measurements show no significant improvement in TP. While there was a small descriptive improvement in the ability to identify if the current event is still ongoing, the ability to identify short or long time intervals remained the same across conditions. In contrast, the caregiver ratings show a significant (observed) improvement for TP. Therefore, we have no consistent support for H3. This discrepancy could be due to either care personnel being too positive about the solution, or our operationalisations of TP not being good enough. Overall, despite the small sample size, large effect sizes and ceiling effects in the primary focus areas of our solution demonstrate a clear improvement in TPA facilitated by AID-Watch.

We also confirm H4 of a positive UX with AID-Watch, as both participant and caregiver ratings were in the "excellent" range (top 10% percentile) of the UEQ-S benchmark [7]. H4 is also supported by our observations of how participants interacted with the device. Involved care personnel expect real-world benefits and the overall potential to enhance quality of life and promote independence. They believe that the participants can benefit from AID-Watch through newly acquired skills and enjoyment of use. They also expect to benefit from AID-Watch themselves by reducing stress and enhancing the quality of care they provide. Additionally, care personnel expect the immediate benefits to further improve with long-term use. These findings highlight a widespread acceptance of the device among both users and care personnel. Consequently, we conclude that AID-Watch holds significant potential as a tool for fostering independence, autonomy, and inclusion.

4.1 Limitations

In favour of ecological validity this research was embedded in adolescents' educational and living facilities. As a trade-off, we could not cater for experimental control of participants, procedures, and conditions. We compensate for this by using methods such as a reversal design and consistent weekdays, which mitigated the issues. Testing in a familiar environment and with known schedules was critical to the validity of the results and the only meaningful way to test the real-world impact of AID-Watch. Despite maintaining distant and neutral interactions, participants may still be influenced by experimenter effects, as indicated by caregivers' reports and participant comments expressing that they were "happy about the experimenters being there". A further limitation was the use of self-translated TPA questionnaires and our operationalisation for measuring TPA. In particular, the measurement of TP should be revised for future research. Therefore, results should not be directly compared with other studies or methods. Generalisability is further limited by the relatively small sample size and narrow sample demographics. However, the large effect sizes make misinterpretation of the overall direction of the effect unlikely.

4.2 Implications for future work

This study was a first summative evaluation of AID-Watch with multiple users and various impairments. It was also the first time AID-Watch was used as a stand-alone solution, without the need for researchers to interfere during usage. While the results are promising for increasing users' TPA and independence, there are further research questions to be addressed. The aim of AID-Watch is to increase TPA and, therefore, target all subcategories of TPA. Currently, the interface mainly targets TO through providing a visual overview of daily activities and TM through reminders. TP is supported by a progress bar which is not as prominent, possibly explaining the differences in results. Further development and user testing will target this feature in more detail, ideally finding a solution with similar results as for TO and TM. In this study, we used the schedules reported by care personnel to create individualised daily schedules for each participant ourselves. However, the organisational role of caregivers as secondary users was omitted. For daily use of AID-Watch, the users' schedules need to be maintainable by caregivers through a simple interface. Leaving the maintenance of the schedule to caregivers in future work, may evoke more usage errors (e.g. forgetting to create events), but could facilitate an easier updating of schedules. This approach would also allow for long-term use over several days or weeks and measurement of learning effects for long-term impact on quality of life and independence. Future research could also look at different living situations. Including people who live alone or with their families, could further improve AID-Watch and elicit more generic insights.

4.3 Conclusion

Our study demonstrates the benefits of cognitive assistance devices to visualise and communicate daily schedules to adolescents with cognitive impairments, and evaluates a smartwatch concept to achieve these benefits. The use of AID-Watch significantly improved participants' TPA in terms of TO and TM. Benefits were measured objectively and rated by caregivers. Additionally, we validated a positive UX with "excellent" benchmark ratings and identified promising benefits for future use, including the potential to increase independence and autonomy for users and reduce stress for caregivers.

4.4 Conflict of Interest

Hauke Wendt and Alexander Kuon are working on a commercial utilisation strategy for the concept to provide an actual solution for people with decreased TPA. To counteract a potential conflict of interest, the study was conducted using an empirical approach and according to scientific principles.

4.5 Acknowledgements

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