Zeitkompass Smartwatch: Promoting Independence in Adults with Cognitive Impairments

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Fig. 1. Zeitkompass is a smartwatch-based cognitive assistance device that provides a personalized and interactive daily schedule to promote independence in individuals with cognitive impairments. The figure illustrates a user wearing Zeitkompass (left) while using the device to communicate an upcoming event with a caregiver (right), highlighting its assistive role in caregiver–user interaction.

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Decreased time-processing ability (TPA) is a common symptom among individuals with cognitive impairments such as autism, attention-deficit/hyperactivity disorder, or dementia. Affected individuals often have difficulty to perceive, orient, and manage time, which reduces their independence in daily life. To promote independent living and reduce caregiver burden, *Zeitkompass* is introduced as a smartwatch-based assistance device offering a personalized, interactive daily schedule. Event-based visualizations with customizable symbols and speech output are designed to make time, activity progress, and upcoming events more accessible. A three-week empirical field evaluation of *Zeitkompass* with eleven adults demonstrated improvements in users' TPA, which subsequently led to increased independence and learning effects. User experience measurements indicate strong acceptance by users and caregivers. Caregivers confirmed quality-of-care improvements through reduced workload and fewer conflicts. Our findings position wearables as promising cognitive assistance devices for sustainable long-term adoption. Future work needs to investigate how the increased independence will reshape user–caregiver relationships.

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1 Introduction

Time management is a fundamental skill for independent living. However, millions of individuals with cognitive impairments face significant difficulties in this domain [23]. Affected individuals such as people with autism, attention-deficit/hyperactivity disorder, or dementia often struggle to understand and utilize clocks, calendars, and schedules, making daily planning and orientation in time highly challenging [2, 14, 19]. These difficulties are conceptually framed as decreased time-processing ability (TPA), a construct defined by the World Health Organization's International Classification of Functioning, Disability and Health [29]. TPA encompasses three subcategories: time orientation (TO), time management (TM), and time perception (TP). Impairments in these domains hinder the ability to structure daily routines, anticipate events, and appropriately allocate time resources. As a result, decreased TPA is strongly associated with loss of independence and autonomy [24], often leading to substantial reliance on caregiver support [8]. This dependency not only limits participation in everyday life but also imposes considerable stress and workload on caregivers [5, 8].

In this work, we present an empirical evaluation of *Zeitkompass*, a commercially available wearable cognitive assistance device [12] previously shown to enhance TPA in adolescents with cognitive impairments [27]. Following a summary of prior research and a description of the *Zeitkompass* system, we present findings from a three-week field evaluation to examine its real-world impact. Our contributions are twofold: (1) we assess whether improvements in TPA through *Zeitkompass* translate into increased independence in daily life, and (2) we extend these findings by examining user experience among primary users and caregivers, as well as providing insights into the device's potential to reshape caregiver–user interactions.

Cognitive assistance devices for time processing have long been proposed as interventions to compensate for decreased TPA and thereby promote independence in daily living. While existing approaches provide evidence that these devices can improve aspects of TPA, their practical impact has remained limited [3, 28]. Earlier systems were subject to technological constraints, which restricted mobility, adaptability, and scalability. As a result, previous solutions offered only partial support and did not achieve seamless integration into users' everyday lives. Beyond technical limitations, social factors have also played a decisive role. Lack of personalization, low acceptance among users and peers, and insufficient caregiver support often led to low adoption and discontinuation [3, 20, 25, 28]. A systematic review by Borgnis et al. highlights that successful implementation depends not only on usability, but also on the broader user experience of both, primary users and caregivers [5]. A perspecitve capturing the device-user-caregiver interaction is therefore essential to ensure that support not only improves TPA in controlled settings but also translates into consistent use in daily life, ultimately fostering independence. Established features to support TPA typically include timely reminders, the provision of an overview of activities, and assistance with planning, which are often implemented through standalone or analog tools such as magnetic boards or timers [3, 4, 28]. *Zeitkompass* combines, optimizes and adapts these features into a wearable format.

Fig. 2. Zeitkompass Smartwatch: The watch face displays upcoming and past events as visual segments with symbols (1) to support TO. The currently active event is highlighted in the center (2) in combination with a circular progress bar (3), facilitating TP. To assist TM, the device offers vibrotactile and auditory reminders at the start and completion of scheduled activities with speech output. Speech output providing information on the current weekday, time, and activity can be activated via button press.

Zeitkompass is a smartwatch-based cognitive assistance device that provides a personalized and interactive daily schedule. The system consists of an accessible smartwatch worn by affected individuals (see Fig. 2), and a companion app for mobile and tablet devices, which is used by caregivers to create and maintain daily schedules (see Fig. 4). The design of *Zeitkompass* has been developed under the working title AID-Watch through an iterative, user-centered design process and refined in a prototype-based summative evaluation by Wendt et al. [27][25]. *Zeitkompass* is based on a Samsung Galaxy Watch (44 mm), which is specifically restricted through device management to disable unnecessary menus and button functions, thereby reducing accessibility barriers for the target user group. This limits the device to essential functions: displaying the *Zeitkompass* watch face and activating speech output via a button press, ensuring usability and accessibility for participants with cognitive impairments (see Fig. 2).

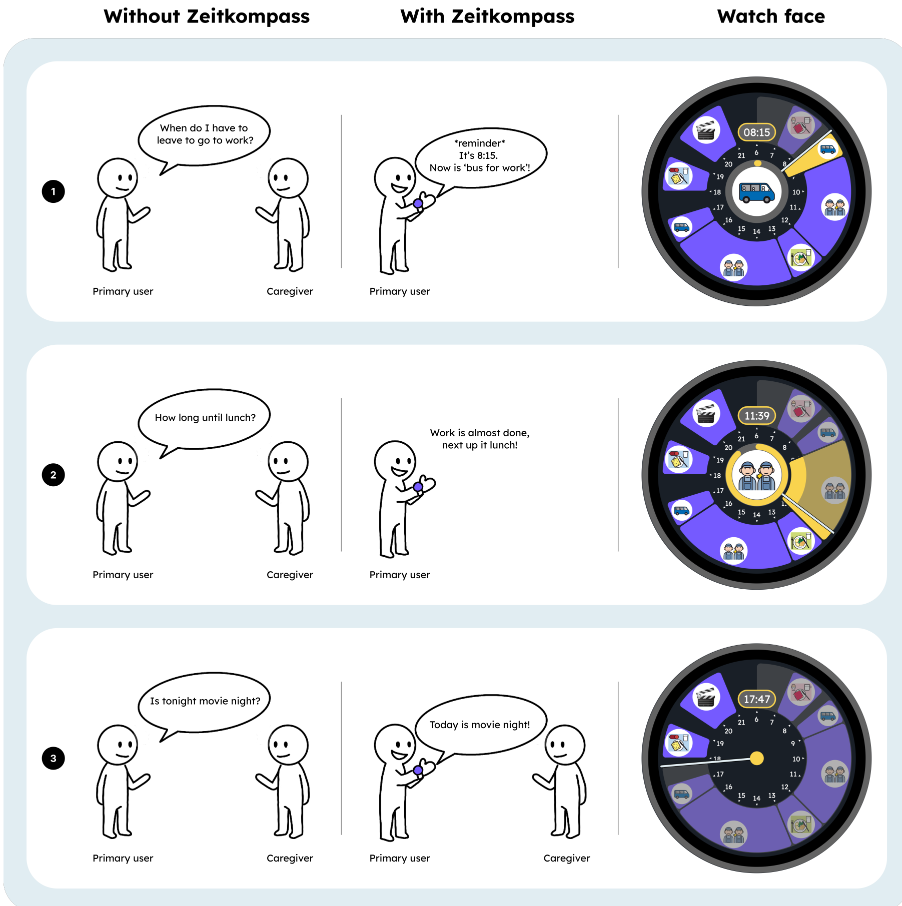

Fig. 3. Illustration of different use scenarios for a sample primary user across one day, comparing situations without and with Zeitkompass. Each scenario is accompanied by the respective Zeitkompass watch face. (1) In the morning, the user receives a reminder to leave for work. (2) During work, the user can independently check the device to answer questions about lunchtime. (3) After work, the user uses Zeitkompass to anticipate highlights of the day and communicate them to caregivers.

This wearable and digital modality is novel for the user group and demonstrated high acceptance by resembling a common smartwatch as well as effectiveness in improving TPA (see Fig. 3), indicating strong potential to also enhance independence [27]. The now commercially available product *Zeitkompass* offers a companion app that enables the creation and maintenance of daily schedules. Synchronization between the app and the watch is managed via WiFi and requires little to no intervention from caregivers. This enables a evaluation of real-world benefits and user adoption for a fully stand-alone solution.

Although assistive technologies are often assessed for their effectiveness, long-term use and adoption remain underexplored [1, 7, 11, 28]. Beyond effectiveness, user experience appears to be a critical factor in translating assistive devices into genuine promoters of independence [6, 7, 28]. While long-term evaluations exist for common assistive technologies, such as mobility aids, research on cognitive assistance devices remains limited [5, 7]. Reported effects on independence and long-term adoption are predominantly qualitative and often lack comparability and empirical evidence of real-world impact [3, 5].

In the German healthcare system, independence represents the central criterion for assessing an individual's needs and determining their entitlement to long-term care benefits. Dependence is therefore classified into five levels of care, ranging from level 1 (minor impairment of independence, requiring minimal assistance with daily activities) to level 5 (severe impairment of independence, requiring extensive and specialized care) [18, 21]. These levels are established through a standardized assessment questionnaire. Importantly, the classification carries substantial real-world implications, as it not only defines the scope of an individual's care but also directly impacts economic resources and quality of care within the healthcare system.

Leveraging the now fully stand-alone system, this study extends prototype-based research in adolescents from Wendt et al. [27] to an empirical evaluation of *Zeitkompass* in a larger cohort of adults with decreased TPA, examined across diverse real-world contexts. With prior results confirming positive effects on TPA, the primary objective of this paper is to assess if these improvements translate to increased independence in daily living, assuming that:

H1 When using *Zeitkompass*, TPA increases in affected individuals.
H2 When using *Zeitkompass*, independence increases in affected individuals.
H3 *Zeitkompass* provides participants with a positive user experience (UX).

2 Method

For a summative evaluation of *Zeitkompass* on participants' independence, the system was used for daily activity planning by caregivers and participants, with participants wearing the watch throughout the study period (see Fig. 4). Structured assessments with participants and caregivers were conducted at regular intervals.

2.1 Study Design and Measurements

The observational study was conducted as a within-subjects design, in which participants wore *Zeitkompass* for three weeks while following their regular daily schedules, with changes prospectively tracked over time. Caregivers supplemented the intervention by maintaining daily schedules and entering key-activities. Since cognitive impairments of participants prevent them from using regular questionnaires (limited reading and processing ability), all hypotheses were operationalized through caregiver assessments of participants' independence, TPA, and UX (proxy-rating). As complementary measures, direct primary user data was collected through verbal TPA assessments and simplified self-reports of UX. Following Wendt et al. [27], we collected data on TPA and UX oriented on their established operationalization. However, in contrast to their emphasis, our study primarily focused on independence as the central outcome.

To measure TPA, we deployed a German TPA questionnaire [27] which is based on the validated KaTid® tool [13] and WHO classifications [29]. For the present study, we extended this questionnaire with an additional item on the TO subscale. It assesses the ability to name the current weekday, which is frequently cited as a key indicator of temporal orientation but had previously been omitted. The TPA questionnaire for caregiver assessment comprised eleven items, each rated on a 7-point Likert scale ranging from "1 - strongly disagree" to "7 - strongly agree". Additionally, researcher-led verbal assessments were used to measure the effects on TPA (see Tab. 1). During post-baseline assessments,

Fig. 4. Zeitkompass companion app for activity planning on tablet and smartphone (prototype in German). Left: Mobile app preview showing the circular Zeitkompass watchface. Center: Mobile app in list view displaying planned activities. Right: Tablet app interface for creating activities, including options for symbol selection, title, weekday, time, and reminder configuration.

participants were allowed to use *Zeitkompass*. Measurements included the participant's ability to name scheduled events of the day and recall already completed events. In addition, participants were asked to identify the current weekday as well as the current and upcoming event, coded as correct or incorrect responses.

The independence of participants was assessed using the standardized dependency assessment tool within the German healthcare system [18, 21]. This questionnaire, designed for care personnel to assess participants' functional independence, comprises six modules: (1) mobility, (2) cognitive and communicative abilities, (3) behavioral and psychological conditions, (4) self-sufficiency, (5) coping with illness- and therapy-related demands, and (6) organization of daily life and social contacts. The questionnaire contains 65 items that are aggregated and weighted to determine the overall "level of care" classification. As a temporal assistance device, *Zeitkompass* is designed to support only specific dimensions of independence. Accordingly, we included only items related to our hypotheses (see Appendix A, Tab. 2), resulting in four items from module 2 (cognitive and communicative abilities) and three items from module 6 (organization of daily life and social contacts). In this assessment (independence-default), each item rated abilities on a 4-point scale from "0 = existent / no impairment" to "3 = nonexistent". To enhance the sensitivity of detecting improvements, the same questionnaire items were reframed to assess perceived improvements through the use of *Zeitkompass* (see Appendix B, Tab. 3). These were rated on a 7-point Likert scale ranging from "1 = strongly disagree" to "7 = strongly agree" for all post-baseline measurements (independence-likert). As an additional instrument to assess independence, suitability and psychosocial impact of *Zeitkompass* in daily use, the Psychosocial Impact of Assistive Devices Scale (PIADS) was administered. The PIADS is a standardized 26-item questionnaire evaluating the effects of assistive devices on functional independence, well-being, and quality of life [15, 16]. After the study phase, caregivers completed the PIADS as proxy-ratings for participants. Items are scored on a scale from "−3 - hinders" to "+3 - improves" and are grouped into the subscales competence, adaptability and self-esteem.

Measurements of UX included both participant self-reports and caregiver assessments. Participants completed an "easy read" version of the UEQ-S, specifically adapted for individuals with cognitive impairments and employing smiley-based response scales instead of traditional Likert items [9]. Caregivers completed the standard UEQ-S as proxy-ratings for participants [26]. To complement the UEQ-S, caregiver satisfaction and ease of use were measured using established short-form usability instruments, chosen to maintain focus on the main hypotheses without unnecessary prolonging the study. The Customer Effort Score (CES) assessed caregivers' ease of use ("How easy was it to use *Zeitkompass* in general for you?") on a 7-point scale ("1 = very difficult", "7 = very easy"), and the Customer Satisfaction Score (CSAT) evaluated overall satisfaction with product use ("How satisfied are you with using Zeitkompass?") on a 5-point scale ("1 = very dissatisfied", "5 = very satisfied").

The study received ethical clearance from the university's ethics committee.

2.2 Participants

We recruited eleven adults within three care and support facilities (four in assisted living setting, seven in domestic setting). Our inclusion criteria required participants to have no prior experience with *Zeitkompass* and cognitive impairments resulting in decreased TPA and reduced independence. Participants were suggested by caregivers based on symptoms rather than specific impairments or diagnoses. The participants (5 male, 6 female) were aged between 18 and 69 years (M = 33.46, SD = 17.85) and had different diagnoses, including autism, down syndrome, or epilepsy, but all of them had either an intellectual or developmental disability. Furthermore, all participants had functional limitations in independence, as indicated by questionnaire ratings on the independence-default measure (M = 1.60, SD = 0.64) for both module 2 (cognitive and communicative abilities) and module 6 (organization of daily life and social contacts). We obtained written consent for participation from the parents or legal guardians of the participants as well as from the respective caregivers, and secured ongoing verbal consent from the participants on each evaluation. One participant withdrew consent after the second evaluation and was therefore excluded from further data collection. Another participant was excluded from data analysis due to incorrect recruitment by the care and support facility, as the baseline TPA measurement (M = 6.55) indicated little to no decrease in TPA. This was further confirmed by the accompanying caregiver. The final analytic sample consisted of nine participants. For ethical and data privacy reasons, demographics were collected at the group level and consequently include the two excluded participants.

2.3 Procedure

The research team provided the watches, while the companion app was installed on the caregiver and / or user devices. Synchronization was enabled via WiFi, requiring both devices to be connected to the environments' WiFi network at the study start. During onboarding, researchers connected the devices and provided an initial demonstration of activity creation to caregivers. Activities were created by selecting a weekday, specifying an activity title, and choosing a symbol. As symbol caregivers could choose either emojis or METACOM symbols, a widely used standard in German care facilities and familiar to both participants and caregivers [17]. Additional parameters, as shown in the right prototype in Fig. 4, included start and end times, recurrence (repeating vs. one-time), and reminders (default at the start and end of an activity, with optional notifications 5, 15 minutes in advance).

The data collection procedure is illustrated in Fig. 5, showing the timing of measurements for our main variables related to H1 and H2. It started with caregivers completing a pre-survey (0_PRE) to establish baseline measurements of TPA and independence (default). In parallel, researcher-led baseline TPA assessments were conducted verbally with participants, following renewed verbal consent and a standardized explanation of the procedure. Subsequently,

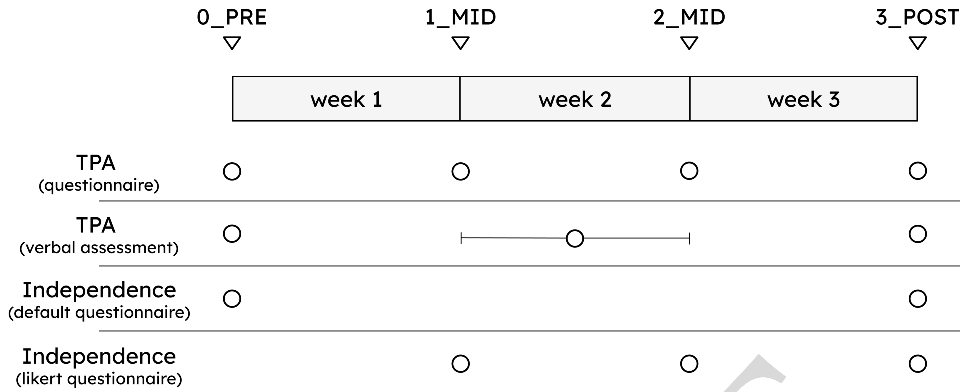

Fig. 5. Visualization of the three-week study design with weekly assessment points, including timepoints for TPA and independence.

participants were equipped with the *Zeitkompass* smartwatch during the onboarding phase. At the onset of each scheduled event, participants received visual and vibrotactile reminders, accompanied by speech output announcing the event's name and time. By pressing a designated button, participants could access additional speech output providing information on the current weekday, time, ongoing activity, and the upcoming activity. After onboarding, caregivers were responsible for creating and maintaining individualized daily schedules via the companion app as well as managing device charging.

Weekly assessments with caregivers were conducted at two midpoints (1_MID, 2_MID), focusing on TPA and independence (likert). Researcher-led verbal TPA assessments were repeated in week two after renewed verbal consent. At the conclusion of the three-week intervention, participants underwent a final TPA assessment and completed the "easy read" version of the UEQ-S on a tablet. Caregivers subsequently filled in the post-survey (3_POST), which included final ratings of perceived independence (default and likert), TPA, and UX. Caregivers also rated their ease of use and satisfaction with *Zeitkompass*. This was complemented by semi-structured interviews with caregivers exploring perceived changes in independence, time orientation, memory, daily structure, caregiver relief, comparisons with existing assistive devices, user experience, perceived usefulness, and overall impressions. A full qualitative analysis of interview data would exceed the scope of this paper. However, we checked whether interview statements invalidated descriptively reported data, which was not the case.

3 Results

The study utilized a repeated-measures design, comprising a baseline assessment followed by three intervention measurements. We report repeated-measures ANOVA and non-parametric alternatives where normality and sphericity could not be assumed.

3.1 Time-processing ability (TPA)

3.1.1 TPA questionnaire. Caregiver ratings of TPA show a significant improvement in a Friedman test ($\chi^2(3) = 18.88$, $p < .001$, $W = 0.70$) across the measurement points from 0_PRE ($M = 3.79$, $SD = 0.87$) to 1_MID ($M = 5.67$, $SD = 0.72$), 2_MID ($M = 5.87$, $SD = 0.96$) and 3_POST ($M = 6.22$, $SD = 0.94$).

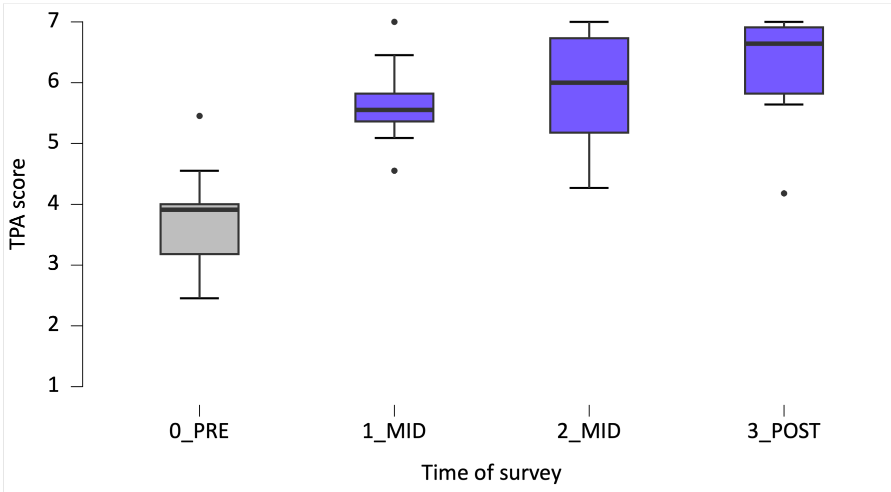

Fig. 6. TPA mean scores across timepoints ($n = 9$), outlining Mdn and IQR. Whiskers represent range of data, excluding individually plotted outliers.

To identify improvements across measurement points, six pairwise comparisons were conducted utilizing the Wilcoxon signed-rank test. A Bonferroni correction was implemented, establishing an adjusted significance threshold of $\alpha = 0.0083$ (0.05/6). The results show significant improvements in TPA scores from 0_PRE to 1_MID ($W = 0.00$, $z = -2.67$, $p = .004$, with a large rank-biserial correlation, $r = -1.00$ ($SE = 0.36$)), 0_PRE to 2_MID ($W = 0.00$, $z = -2.67$, $p = .002$, $r = -1.00$ ($SE = 0.36$), and 0_PRE to 3_POST ($W = 0.00$, $z = -2.67$, $p = .002$, $r = -1.00$ ($SE = 0.36$). In contrast, comparisons between subsequent measurement points did not meet the Bonferroni-corrected significance threshold (all $p > 0.0083$): 1_MID vs. 2_MID ($W = 10.00$, $z = -0.68$, $p = .277$), 1_MID vs. 3_POST ($W = 5.00$, $z = -1.82$, $p = .040$), and 2_MID vs. 3_POST ($W = 3.00$, $z = -2.10$, $p = .021$).

3.1.2 Verbal TPA assessements. The reliability of verbal TPA assessements is limited by day-dependent fluctuations, communicative impairments, and poor comparability of daily schedules, necessitating cautious interpretation due to high standard deviations. For descriptive purposes we will still report mean scores across 0_PRE, MID, and 3_POST measurement points for each question (see Tab. 1).

3.2 Independence

3.2.1 Independence-default questionnaire. Caregiver assessments on the participants' independence, show a significant reduction in dependency, as demonstrated by a paired samples t-test ($t(8) = 2.60$, $p = .011$, $d = 0.87$), when comparing baseline ratings ($M = 1.60$, $SD = 0.42$) with 3_POST ratings ($M = 1.14$, $SD = 0.65$).

3.2.2 Independence-likert questionnaire. A Wilcoxon signed-rank test indicated that the median Likert rating for independence improvements ($M = 5.72$, $SD = 0.61$) was significantly greater than the null hypothesis value of 4 ("neither agree nor disagree" - neutral), $V = 325$, $p < .001$ (one-tailed), rank-biserial correlation $r = 1.00$ ($SE = 0.23$).

A repeated-measures ANOVA indicated a significant improvement of Likert ratings on independence-items, $F(2, 16) = 17.35$, $p < .001$, $\eta^2 = 0.68$. Descriptive scores increase progressively (see Fig. 7) from 1_MID ($M = 5.37$, $SD = 0.52$)

Table 1. *Mean scores of verbal TPA assessment items across timepoints. Original German items are listed with English translations in parentheses.*

Item	0_PRE	MID	3_POST
Welche Pläne hast du heute noch? Was wirst du heute noch machen? (What plans do you have for today? What will you still do today?)	0.41 (SD = 0.28)	0.49 (SD = 0.37)	0.48 (SD = 0.27)
Was hast du heute schon gemacht? Welche Pläne hattest du heute? (What have you already done today? What plans did you have today?)	0.31 (SD = 0.24)	0.48 (SD = 0.40)	0.40 (SD = 0.36)
Welchen Termin hast du jetzt? Was machst du gerade? (What appointment do you have now? What are you doing right now?)	0.70 (SD = 0.48)	0.63 (SD = 0.52)	0.71 (SD = 0.49)
Was machst du als Nächstes? Was kommt danach? (What will you do next? What comes afterwards?)	0.50 (SD = 0.53)	0.57 (SD = 0.53)	0.86 (SD = 0.38)
Welcher (Wochen-)Tag ist heute? (What [week]day is today?)	0.80 (SD = 0.42)	0.63 (SD = 0.52)	1.00 (SD = 0.00)

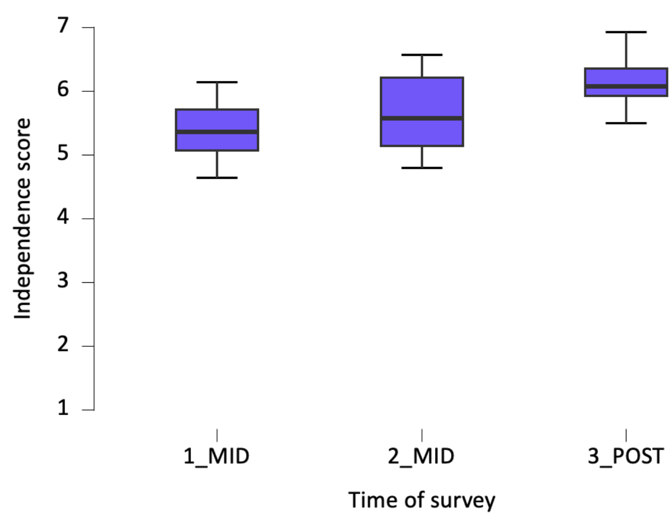

Fig. 7. Independence-likert mean scores across timepoints (n = 9), outlining Mdn and IQR with whiskers representing the range.

to 2_MID (M = 5.66, SD = 0.66), and further to 3_POST (M = 6.14, SD = 0.41). Post-hoc tests confirmed significant improvements from 1_MID to 3_POST ($t = -5.830$, $p_{\text{holm}} < .001$) as well as from 2_MID to 3_POST ($t = -3.644$, $p_{\text{holm}} = .004$), indicating learning effects.

3.2.3 PIADS Questionnaire. The psychosocial impact of *Zeitkompass* on functional independence, well-being, and quality of life was assessed using the PIADS. Across all items, results indicate a positive impact with an overall mean score of M = 1.74 (SD = 0.63, n = 27). Subscale analyses further indicated consistently favorable ratings for competence (M = 1.84, SD = 0.47, n = 9), adaptability (M = 1.96, SD = 0.78, n = 9), and self-esteem (M = 1.42, SD = 0.50, n = 9).

3.3 User Experience

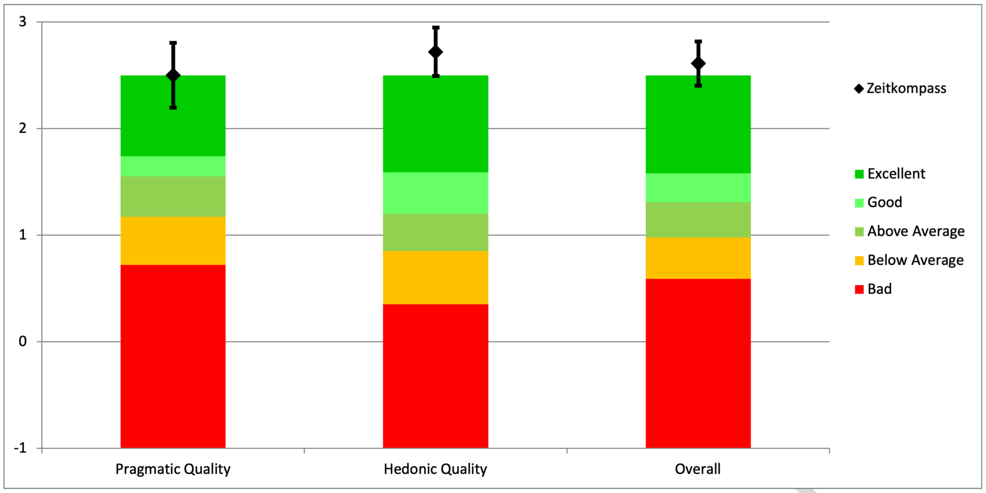

Fig. 8. Combined mean UEQ-S self- and proxy-ratings for *Zeitkompass* across all subscales, compared with international benchmark data [10]. Results position the UX within the "excellent" category.

3.3.1 UEQ-S Questionnaire. Participants using *Zeitkompass* reported an average UEQ-S score of 2.66 (n = 8, SD = 0.34), while caregivers reported an average score of 2.57 (n = 9, SD = 0.52) for UX observed in participants. Both correspond to "excellent" UX, ranking in the highest 10% of the UEQ-S benchmark.

Combining both datasets (n = 17) yielded an overall score of M = 2.61 (SD = 0.43) as well as subscale scores of 2.50 (n = 17, SD = 0.64) for pragmatic quality and 2.72 (n = 17, SD = 0.43) for hedonic quality (see Fig. 8).

3.3.2 Customer Effort Score (CES) Questionnaire. Caregivers reported a high level of ease of use with an average score of M = 6.22 (SD = 0.83) on a 7-point scale.

3.3.3 Customer Satisfaction Score (CSAT) Questionnaire. Caregivers also reported a very high satisfaction level, with an average score of M = 4.78 (SD = 0.44) on a 5-point scale.

4 Discussion

This research empirically evaluated *Zeitkompass* as a wearable cognitive assistance device in real-world contexts. Our goal was to go beyond confirming positive effects of assistive devices on individuals' TPA and assess resulting impact on increasing independence in daily living.

Supporting previous evaluations from Wendt et al. [27], the present study demonstrates that *Zeitkompass* significantly improved participants' TPA. Consequently, primary users gained greater functional abilities, including the ability to review upcoming activities, rely on reminders, and communicate their daily schedules to others through the device rather than through constant caregiver queries. Caregiver assessments indicated large effect sizes, thereby confirming H1. While additional researcher-led verbal TPA control assessments showed slight descriptive improvements, the interpretability of these results is very limited. Although reliable in prototype studies from Wendt et al. [27], the approach proved less suitable in this more heterogeneous and ecologically valid setting. Inconsistent results likely arose from day-to-day fluctuations (as stated by caregivers), communicative impairments, and the limited comparability of individual daily schedules. Caregivers emphasized that the assessments were not fully representative of participants' actual skills. We conclude that such verbal TPA measures are informative in early-stage prototype testing under close supervision but lack scalability for larger field trials with diverse user groups. In general, the observed effect sizes from caregiver proxy-ratings and consistency with previous research reduce the likelihood of misinterpreting the effects [27].

In the adoption of assistive technology for individuals with cognitive impairments, de Joode et al. [7] highlighted the importance of considering not only cognitive functioning but also social functioning, as the latter often reflects the actual practical effectiveness of the device. Beyond cognitive improvements in TPA, the results also provide strong evidence for improved independence through *Zeitkompass*, thereby confirming H2. Confirmed by both independence measures (default and likert), the results demonstrate robust improvements. The less sensitive independence-default questionnaire already indicated significant pre- to post-intervention gains with large effect sizes. In parallel, the independence-likert ratings indicated a significant main effect with a consistent upward trend across measurement points, suggesting a sustained development in independence throughout the intervention. Importantly, post-hoc comparisons revealed strong improvements from both mid-intervention measurements to post-intervention values, indicating clear learning effects. This progression implies that independence not only increased with intervention but also continued to improve over time. As additional measures for functional independence, PIADS scores indicated that the use of *Zeitkompass* was associated with improvements in perceived competence, adaptability, and self-esteem, reflecting a broadly beneficial psychosocial impact. Overall, despite the small sample size and participant exclusions, the large effect sizes and observed learning effects provide clear evidence that *Zeitkompass* improves independence in daily living.

The results also support a positive user experience for participants, thereby supporting H3. Both self-reports and caregiver proxy-ratings evaluated the UX with *Zeitkompass* within the "excellent" range (top 10% percentile) of the UEQ-S benchmark [10]. Caregivers also reported positive experiences, indicated by high levels of ease of use and satisfaction with the *Zeitkompass* system, including both the watch and companion app. Furthermore, they confirmed reduced stress and improved quality of care, noting that both participants and they themselves benefited from the device. These findings are consistent with previous research that demonstrates the effectiveness of assistive technology in reducing caregiver burden [8, 22].

It also resonates with the concept of independence as a central criterion for assessing the "level of care" and associated benefits, such as caregiver support, within the German healthcare system [18, 21]. As emphasized by Borgnis et al. [5], there remains a need for standardized methods to evaluate individual assistive technology interventions. In this study, we introduce the novel use of a real-world assessment instrument already employed in the German healthcare system to determine degrees of dependence. This questionnaire proved useful in operationalizing multiple dimensions of independence in real-world evaluation. With six modules covering distinct domains, it offers both adaptability across contexts and sufficient standardization to ensure practical relevance. It may thus be a promising approach toward greater standardization in assistive technology intervention research, justifying closer examination in future research.

Caregivers further emphasized that *Zeitkompass* was perceived as a low-threshold, mobile solution to promote independence, in contrast to other assistive devices that are often complex and lack acceptance. Design implications from Dawe [6] highlight the importance of achieving the right balance between easy-to-use software and suitable hardware to ensure portability. While smartwatch-based cognitive aids represent a novel modality for the user group, the results indicate that *Zeitkompass* achieved this balance.

We conclude that especially the wearable form factor is a key driver for this effectiveness and acceptance. Unlike conventional assistive devices, a smartwatch carries little to no stigma. It's a more mobile and therefore more consistent way to serve users. It also seemed to be recognized more as an extension of the user rather than as an external reminder or directive. Caregivers reported that notifications, such as bedtime announcements, were often perceived as self-initiated rather than negatively connoted caregiver instructions. This, in turn, enhanced users' self-esteem and sense of control. The resulting shift reportedly reduced potential for conflict, facilitated collaboration and communication, and empowered both primary users and caregivers, underscoring the device's potential to reshape caregiver–user interaction.

5 Limitations

To maximize ecological validity, this research was embedded in participants' everyday lives. As a trade-off, experimental control over participants, procedures, and conditions was limited. The testing of *Zeitkompass* in real-world contexts and actual daily schedules was critical to assessing its practical impact and the only meaningful approach to evaluating its real-world effectiveness. The operationalized independence questionnaire is not primarily designed to assess interventions like *Zeitkompass* but to track care dependency over time. However, our findings suggest that it may serve as a reliable proxy measure to evaluate real-world impacts directly related to care levels. Generalizability could be limited by the small sample size and the exclusions of participants. However, the observed large effect sizes and the consistency with prior research results from Wendt et al. [27] provide confidence in the validity of the observed effects.

6 Implications for future work

This study summatively evaluates *Zeitkompass*, an assistive device that improves TPA, incorporating caregivers as secondary users for the first time. While the findings are promising, there are further directions for future research and development. First, the current device focuses on TPA within the scope of daily activities. Future iterations could extend functionality to support temporal orientation across broader time frames, such as weeks or months. This may provide additional benefits in creating awareness for plans and enhancing users' independence. Second, although the companion app was well accepted by caregivers, its use in care facilities is constrained by the need to manage multiple clients simultaneously. Enhancing the app with features that facilitate efficient multi-user schedule maintenance could further improve adoption in these contexts. Third, demographic patterns across this and prior work from Wendt et al. [27] suggest that *Zeitkompass* is effective for adolescents and adults. Future studies should target elderly populations, particularly individuals with dementia, who represent a major group affected by TPA impairments and may also benefit from such interventions. Finally, long-term research is required to investigate the sustainability of observed learning effects and to explore the broader impact of *Zeitkompass*, including autonomy, user–caregiver interaction, and quality of life. Beyond its role in supporting TPA and independence, the device may function as a communication aid that reduces conflict potential and fosters more collaborative care relationships. Exploring these dynamics, as well as the integration of *Zeitkompass* with complementary support strategies, could provide deeper insights into the potential of wearable cognitive assistance devices as support solutions in care.

7 Conclusion

Our findings demonstrate that wearable cognitive assistance devices are an effective means of promoting independence in daily life among individuals with cognitive impairments. Building on previous prototype-based research, this study evaluated *Zeitkompass*, a smartwatch-based solution designed to address the limitations and issues of existing concepts. The empirical evaluation of the wearable in real-world contexts further confirmed significant improvements in participants' TPA, which successfully translated into significantly increased independence. Furthermore, participants'

UX was rated “excellent” in benchmark ratings, while caregivers reported high levels of ease of use and satisfaction, confirming strong acceptance in both groups. These are critical factors for long-term adoption and successful device-user-caregiver interaction. Caregiver-rated quantitative questionnaires and assessments demonstrated the practical relevance of the device in everyday life also indicating a reduced workload for caregivers by minimizing repetitive questions and conflicts. Therefore this wearable extends beyond improvements in TPA-related skills to broader impacts such as independence, user empowerment and the potential to reshape caregiver–user interaction. We hope this research contributes to the development of new approaches that combine wearable devices with complementary support strategies to promote greater quality of care and independence for people with cognitive impairments.

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A Independence-default questionnaire

Table 2. Selected items for independence-default questionnaire with examples (German original and English translation).

Module	Item	German (Original)	English (Translation)
2	4.2.3	Zeitliche Orientierung: Wie gut kann die VP sich zeitlich orientieren (z. B. Uhrzeit erkennen, Tageszeiten unterscheiden)?	Temporal orientation: How well can the participant orient in time (e.g., recognize the time, distinguish times of day)?
2	4.2.4	Erinnern an wesentliche Ereignisse: Wie gut kann die VP sich an wichtige Termine oder Ereignisse erinnern (z. B. Arzttermine, feste Routinen)?	Remembering essential events: How well can the participant recall important appointments or events (e.g., medical visits, fixed routines)?
2	4.2.5	Steuern von mehrschrittigen Alltagshandlungen: Wie gut kann die VP zeitliche Abfolgen verstehen und einhalten (z. B. Reihenfolge von Aktivitäten wie „zuerst frühstücken, dann anziehen“)?	Managing multi-step activities: How well can the participant understand and follow temporal sequences (e.g., order of activities such as “first breakfast, then get dressed”)?
2	4.2.11	Beteiligen an einem Gespräch: Wie gut kann die VP an Gesprächen teilnehmen (z. B. aktives Zuhören, Beantworten von Fragen, Berichten vom Tag)?	Participating in conversations: How well can the participant engage in conversations (e.g., active listening, answering questions, recounting daily events)?
6	4.6.1	Gestaltung des Tagesablaufs: Wie gut kann die VP ihren Tagesablauf selbstständig gestalten (z. B. Aufstehen, Mahlzeiten einnehmen, Freizeitaktivitäten planen) und auf Veränderungen reagieren?	Structuring daily routine: How well can the participant organize their daily routine independently (e.g., getting up, eating meals, planning leisure activities) and respond to changes?
6	4.6.2	Ruhen und Schlafen: Wie gut kann die VP Ruhe- und Schlafphasen regulieren (z. B. Einhalten eines Schlafplans)?	Rest and sleep: How well can the participant regulate rest and sleep phases (e.g., sticking to a sleep schedule)?
6	4.6.4	Vornehmen von in die Zukunft gerichteten Planungen: Wie gut kann die VP zukünftige Aktivitäten planen (z. B. Planen von Verabredungen)?	Future planning: How well can the participant plan future activities (e.g., scheduling appointments)?

B Independence-likert questionnaire

Table 3. Reframed independence questionnaire items to assess perceived improvements trough the use of *Zeitkompass* with examples (German original and English translation).

Module	Item	German (Original)	English (Translation)
2	4.2.3	**Zeitkompass verbessert zeitliche Orientierung:** Die VP kann sich mit Zeitkompass besser zeitlich orientieren (z. B. Uhrzeit erkennen, Tageszeiten unterscheiden).	**Zeitkompass improves temporal orientation:** The participant can orient in time better with Zeitkompass (e.g., recognize the time, distinguish times of day).
2	4.2.4	**Zeitkompass verbessert Erinnern an wesentliche Ereignisse:** Die VP kann sich mit Zeitkompass besser an wichtige Termine oder Ereignisse erinnern (z. B. Arzttermine, feste Routinen).	**Zeitkompass improves remembering essential events:** The participant can better recall important appointments or events with Zeitkompass (e.g., medical visits, fixed routines).
2	4.2.5	**Zeitkompass verbessert Steuern von mehrschrittigen Alltagshandlungen:** Die VP kann mit Zeitkompass besser zeitliche Abfolgen verstehen und einhalten (z. B. Reihenfolge von Aktivitäten wie „zuerst frühstücken, dann anziehen“).	**Zeitkompass improves managing multi-step activities:** The participant can better understand and follow temporal sequences with Zeitkompass (e.g., order of activities such as “first breakfast, then get dressed”).
2	4.2.11	**Zeitkompass verbessert Beteiligen an einem Gespräch:** Die VP kann mit Zeitkompass besser an Gesprächen teilnehmen (z. B. aktives Zuhören, Beantworten von Fragen, Berichten vom Tag).	**Zeitkompass improves participation in conversations:** The participant can better engage in conversations with Zeitkompass (e.g., active listening, answering questions, recounting daily events).
6	4.6.1	**Zeitkompass verbessert Gestaltung des Tagesablaufs:** Die VP kann mit Zeitkompass ihren Tagesablauf besser selbstständig gestalten (z. B. Aufstehen, Mahlzeiten einnehmen, Freizeitaktivitäten planen) und auf Veränderungen reagieren.	**Zeitkompass improves daily structuring:** The participant can better organize their daily routine with Zeitkompass (e.g., getting up, meals, leisure) and adapt to changes.
6	4.6.2	**Zeitkompass verbessert Ruhen und Schlafen:** Die VP kann mit Zeitkompass besser Ruhe- und Schlafphasen regulieren (z. B. Einhalten eines Schlafplans).	**Zeitkompass improves rest and sleep:** The participant can better regulate rest and sleep phases with Zeitkompass (e.g., maintaining a sleep schedule).
6	4.6.4	**Zeitkompass verbessert Vornehmen von in die Zukunft gerichteten Planungen:** Die VP kann mit Zeitkompass besser zukünftige Aktivitäten planen (z. B. Planen von Verabredungen).	**Zeitkompass improves future planning:** The participant can better plan future activities with Zeitkompass (e.g., scheduling appointments).