Assessing the Acceptability Towards a Tangible Robot-like Neurofeedback Companion for Neurofeedback Training: The Role of ADHD and Work Status

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No AI technologies have been used to produce any content in this thesis. I acknowledge that I utilized AI tools, such as ChatGPT (OpenAI, 2023) and Grammarly for assistance in improving my writing (e.g. grammar checks, synonym generation, and translation from Dutch to English). Example prompts used are: “What is the best synonym for thus or hence”, “Translate: om te bepalen dat dit zo is”.

The maximum word count of this thesis was extended to 6500 words in accordance with our supervisor.

Note: This thesis exceeds this word count of 6500 words due to a large table in the text. Without the table, the word count is not exceeded. This is in accordance with our supervisor.

Abstract

Introduction: People with ADHD often experience cognitive problems (e.g. executive dysfunction) and need cognitive training options. Neurofeedback can be the solution, but there are 30-50% non-responders. With the help of a tangible robot-like neurofeedback companion, people can get real-time feedback during neurofeedback training sessions. This helps personalize the sessions and tackle learning variability. Next to assessing acceptability, ADHD and work status will be taken into account. **Methods**: This feasibility-acceptability study used a convenience sample (N = 102). All participants filled in an online questionnaire assessing three different aspects of acceptability (perceived usefulness, perceived ease of use, and behavioural intention). The analysis included an independent samples t-test and two two-way ANOVAs. **Results**: The overall acceptability across the sample reached the threshold of 60 (scale 0-100). The independent samples t-test indicated a statistical trend between people with ADHD and neurotypical individuals on perceived usefulness (p = .09). The two-way ANOVAs indicated no significant differences between having ADHD or being neurotypical on perceived ease of use and behavioural intention, even as no significant differences regarding different work statuses for perceived ease of use and behavioural intention. There were also no significant interaction effects. **Discussion and conclusions**: The use of a tangible robot-like neurofeedback companion could improve the outcomes of neurofeedback training and could be used more broadly in healthcare, because it is personalized and adapted to the individual. Before introducing the tangible robot-like neurofeedback companion, more research should be done focusing on bigger and more equal group regarding work status and ADHD.

Key words: neurofeedback, tangible robot-like neurofeedback companion, new technologies, feasibility study, acceptability, ADHD, work status

Assessing the Acceptability of a Tangible Robot-like Neurofeedback Companion for Neurofeedback Training: The role of ADHD and Work Status

The number of people dealing with cognitive problems is rising in people from all age groups and multiple backgrounds, and there is a need for intervention programmes (Bai et al., 2022; Olness, 2003). Computerized cognitive training (CCT) is one of those intervention programmes that improves cognition. This training is used in practice and within a broad spectrum of disorders (e.g., depression, attention-deficit/hyperactivity disorder, and dementia) (Chan et al., 2024; Motter et al., 2015; Stern et al., 2014). Although CCT is associated with improvement in working memory, attention, and global functioning, there is no effect of CCT for executive functioning (Motter et al., 2015). In contrast, the systematic review from Viviani and Vallesi (2021) reports that there have been hints at an effect in improving executive functioning in EEG-neurofeedback training. Executive functions are general control systems in the brain that help manage and guide other thinking processes (Miyake et al., 2000).

Neurofeedback is another promising intervention programme for training specific brain activity relevant to cognition (Loriette et al., 2021; Viviani & Vallesi, 2021). In neurofeedback training participants learn to control their brain activity in specific brain areas using real-time feedback from their own brain activity (Enriquez-Geppert et al., 2017; Holtmann et al., 2014; Kadosh & Staunton, 2019; Weber et al., 2020). In general, there are multiple neurofeedback techniques, for example with the use of functional Magnetic Resonance Imaging (fMRI), electroencephalogram (EEG), or Brain-Computer Interfacing (BCI) (Kadosh & Staunton, 2019).

Despite hints at success for neurofeedback training, there are also 30-50% of participants unable to influence their brain activity (Alkoby, 2018; Kadosh & Staunton, 2019). These participants are referred to as non-responders. Even though those participants did not respond to

the neurofeedback training given in that particular study, there is no further research on those groups to see whether the non-responders are generally unable to regulate and modify their brain activity or if they could respond in another study (Kadosh & Staunton, 2019). This problem of non-responsiveness is a general challenge in healthcare (pharmacological and psychological) (Carrington et al., 2024; Semmlinger et al., 2024; Vinciguerra et al., 2021). The meta-analysis from Gloster et al. (2019) shows that non-responsiveness to psychological treatment occurs in one third of patients. Variability in neurofeedback performance is another obstacle in neurofeedback training (Alkoby et al., 2018). Each individual has their own pathways in their brain and will need the training to be adjusted to them. Having a personalized neurofeedback training for everyone participating can turn non-responders into responders or into improving their performance level (Alkoby et al., 2018). Personalization is a well-known topic for interventions, ranging from technology-supported personalised learning to personalised dietary interventions (De Roos & Brennan, 2017; Major et al., 2021; Rivera-Romero et al., 2023) and this is also needed for neurofeedback.

The introduction of a tangible robot-like neurofeedback companion could be beneficial to neurofeedback as it can create personalization and thereby tackle the non-response and learning variability. A tangible robot-like neurofeedback companion is a non-human computer-based intelligent tutoring system that facilitates learning through social interaction, without authoritarian influence (Chou et al., 2003). A tangible robot-like neurofeedback companion gives real-time feedback on how the participant is progressing and performing during the neurofeedback training and can help people decide which strategy works the best in improving brain activity (Pillette et al., 2020). Strategies are ways to think about something and hoping the brain activity goes up in a certain brain area (e.g. frontal-midline theta waves in the midcingulate

cortex), for example thinking about entering your childhood home or thinking about the first dog you owned. Neurofeedback relies on operant conditioning and thus having a 'good' strategy that leads to enhanced brain activity promotes individuals to continue using that strategy (Enriquez-Geppert et al., 2014). During neurofeedback with a tangible robot-like neurofeedback companion, participants will not only see their brain activity during the neurofeedback training, but they will also hear the tangible robot-like neurofeedback companion talk in between sessions to promote changing strategies for optimal brain activity and give positive encouragements. Pillette et al. (2020) incorporated a tangible robot-like neurofeedback companion in their study on Mental-Imagery Brain-Computer Interfaces and found promising results regarding learning and memorability scores, and improvement in efficiency. Even though there have been successful reports of improvement in performance with the help of a tangible robot-like neurofeedback companion in Mental-Imagery Brain-Computer Interfaces users (Pillette et al., 2020), feasibility studies are needed for the integration of a tangible robot-like neurofeedback companion into the practice of neurofeedback.

A feasibility study is used to determine whether an intervention can be used for further testing (Bowen et al., 2009). The term 'feasibility study' is used to refer to any type of investigation that assists researchers in preparing for full-scale intervention research. This is important, because this enables researchers to identify if their research methods or protocols need modification (Bowen et al., 2009). But this is also essential for testing if new ideas before they become widely available. Acceptability is one form of assessing if something is feasible and is necessary for the effectiveness of an intervention (Sekhon et al., 2017). Acceptability represents an individual's initial attitudes and expectations towards new technologies or interventions before using them (Barcenilla & Bastien, 2010; Février, 2011). It provides valuable insights into

the factors influencing users' initial engagement with new technologies, as well as the underlying rationale that shapes their continued adoption and use (Alexandre et al., 2018).

Grevet et al. (2023) assessed acceptability using the Technology Acceptance Model (TAM3) (Venkatesh & Bala, 2008). This is a model that covers three domains of acceptability: perceived usefulness, perceived ease of use, and behavioural intention. It is needed to look at these three domains separately, because they all contribute to different assets from acceptability. Perceived usefulness is about the personal feeling about the utility of a system. Perceived ease of use is the degree of belief to which using the system will require little or no effort. Lastly, behavioural intention is about the intention to use a new technology, such as a tangible robot-like neurofeedback companion (Grevet et al., 2023). These three domains contribute to the possibility of demonstrating "use behaviour", meaning that a person really uses a new technology. The use of an acceptability model is highly relevant to the field of clinical neuropsychology, because tools used in clinical neuropsychology (e.g. new interventions or methods) must be tested for acceptability before introducing it in clinical practice to see if something needs change to better fit the user (Bowen et al., 2009).

To ensure inclusion of diverse groups of people, this study focuses on individuals with different work statuses, and next to that people with ADHD and neurotypical individuals are considered. Attention-deficit/hyperactivity disorder (ADHD) is characterized by high levels of inattention and/or hyperactivity/impulsivity and is associated with impairments in academic, occupational, and social functioning, and next to that having ADHD is associated with a psychiatric burden and reduced quality of life (QoL). Fuermaier et al. (2021) reported that ADHD can have a great impact on work performance in adults, showing lower performance in adults with ADHD in the workplace. Albrecht et al. (2015) showed that people with ADHD can

compensate difficulties in other domains by acquiring self-regulation skills through neurofeedback. Neurofeedback could help people with ADHD perform better at work, but employment status (full-time, part-time, or unemployed) was not considered during this study. Sjöwall et al. (2023) also speak about people not responding to ADHD-medication or not wanting to take ADHD medication, suggesting a need non-pharmacological treatment options.

Neurofeedback could be a treatment that enhances executive functioning like working memory updating, whereas CCT could not. The link between neurofeedback and ADHD has been researched a number of times and there are mixed findings regarding improving ADHD symptoms with neurofeedback. Albrecht et al. (2015) reports promising results regarding improvement of ADHD symptoms (hyperactivity and attention) with neurofeedback in children, and also a small improvement of executive functioning. In contrast, the meta-analysis from Cortese et al. (2016) fails to support neurofeedback as an effective treatment for ADHD. They think this could be due to no standard neurofeedback protocols that ensure learning and optimise clinically relevant transfers. By adding a tangible robot-like neurofeedback companion the outcomes could be more positive through the use of personalized feedback on the chosen strategies and positive encouragements during the neurofeedback training. A tangible robot-like neurofeedback companion could ensure learning and therefore be better suitable for individuals with ADHD.

Besides looking at ADHD, work status might play a role in the acceptability towards neurofeedback training with a tangible robot-like neurofeedback companion, because the training is time-consuming and takes effort to complete (Sjöwall et al., 2023). People working full-time jobs report higher drop-out rates from neurofeedback training studies than people working part-time jobs (Mawjee et al., 2019). Neurofeedback training consists of multiple sessions and

requires effort from the participants, and this could be a factor for people to drop-out. This is in contrast to pharmacological treatment options that consist of taking a pill and does not require effort.

There is still too little research on adding a tangible robot-like neurofeedback companion to neurofeedback training sessions and the acceptability from the general public to this new technology. This present study will therefore focus on the first part (acceptability) of adding a new technology into the already existing procedure of neurofeedback. The aim is to look at different backgrounds of a big group of individuals from all ages and see how they score on the three different acceptability domains (perceived usefulness, perceived ease of use, behavioural intention). Another aim of this study is to see where the differences are in people with ADHD and different works statuses on the acceptability domains. People with ADHD will be compared to neurotypical individuals, meaning people without any area of neurodivergence, such as ADHD, autism, or dyslexia (Davies et al., 2023). Looking at the three different domains of acceptability is helpful to know where an intervention can be added and in which domain there is the most terrain to win. The research questions flowing out of this, are: (1) “Do individuals with ADHD perceive a tangible robot-like neurofeedback companion differently during neurofeedback training compared to neurotypical individuals?” and (2) “Does work status influence perceived ease of use and behavioural intention towards a tangible robot-like neurofeedback companion during neurofeedback training in individuals with ADHD compared to neurotypical individuals?”

In this study the link between ADHD and acceptability will be investigated, as well as the link between work status and acceptability. In addition, the interaction between ADHD and work status will be explored. The hypotheses for the research questions about these domains are:

H1: There is a statistically significant difference in perceived usefulness between the ADHD group and the neurotypical group, where people with ADHD see a tangible robot-like neurofeedback companion as more useful than neurotypical individuals.

$H0_1$: There is no significant difference in perceived usefulness between the ADHD group and the neurotypical group.

H2: Having ADHD is associated with higher perceived ease of use towards a tangible robot-like neurofeedback companion compared to neurotypical individuals (statistically significant main effect). And being full-time employed is associated with lower perceived ease of use towards a tangible robot-like neurofeedback companion compared to being part-time employed, unemployed, student, or "other" (statistically significant main effect). Additionally, the influence of work status on perceived ease of use is higher in individuals with ADHD than in neurotypical individuals (statistically significant interaction effect).

$H0_2$: Having ADHD is not associated with higher perceived ease of use towards a tangible robot-like neurofeedback companion compared to neurotypical individuals. And being full-time employed is not associated with lower perceived ease of use towards a tangible robot-like neurofeedback companion compared to being part-time employed, unemployed, student, or "other". Additionally, there is no influence of work status on perceived ease of use in individuals with ADHD than in neurotypical individuals.

H3: Having ADHD is associated with higher behavioural intention towards a tangible robot-like neurofeedback companion compared to neurotypical individuals (statistically significant main effect). And being full-time employed is associated with lower behavioural intention towards a tangible robot-like neurofeedback companion compared to being part-time employed, unemployed, student, or "other" (statistically significant main effect). Additionally,

the influence of work status on behavioural intention is higher in individuals with ADHD than in neurotypical individuals (statistically significant interaction effect).

$H0_3$: Having ADHD is not associated with higher behavioural intention towards a tangible robot-like neurofeedback companion compared to neurotypical individuals. And being full-time employed is not associated with lower behavioural intention towards a tangible robot-like neurofeedback companion compared to being part-time employed, unemployed, student, or "other". Additionally, there is no influence of work status on behavioural intention in individuals with ADHD than in neurotypical individuals.

Methods

Recruitment and Inclusion Criteria

The recruitment of the participants has been done through the network of bachelor students and the TULIP research team, the use of flyers and social media, SONA, and through writing emails to professionals who work in a psychological context. The minimum age for participating was eighteen years old and understanding one of the following languages was crucial: Dutch, English, Spanish, German, or French, as the questionnaire was available in these languages. The collection of the data started in February 2024 and ended in April 2025. The study questionnaire (PSY-2324-S-0092 *TULIP-acceptability study*) was approved by the Ethical Committee of the Behavioural and Social Science Faculty of the University of Groningen, Netherlands, and conducted in accordance with the Declaration of Helsinki.

Participants

This study used a convenience sample. There were *854* adult participants collected from different countries. The mean age was 29.03 years (*SD* = 15.04). The gender distribution is: 65.81% of the participants were women (n = 562), 20.26% were men (n = 173), 2.93% fell in the category "other" (n = 25) (this includes agender, androgyne, demigender, genderqueer, gender

fluid, questioning, unsure, and ‘another gender category’), and there were 11.01% of people who did not fill in anything regarding gender (n = 94). Participants were provided with information about their involvement before taking part in the study, as well as a description of how their data will be used following the ethical principles that protect the rights and well-being of participants. They gave informed consent to participate.

Procedure and Materials

The questionnaire was created and distributed using Qualtrics. The participants completed the questionnaire on their own devices. The estimated duration required to complete the questionnaire is approximately thirty minutes. They had to sign the informed consent form in order to start the questionnaire.

Demographics Questionnaire

In the first part of the survey, questions related to sociodemographic background (age, gender, work status, completed education, residency, nationality, medical or health-related profession, history of psychiatric or neurological conditions) were administered.

Questions Regarding Experienced Cognitive Problems

Cognitive problems were measured using 14 items in which participants rated their response on a 3-point scale: *Yes, strongly*, *Yes, slightly*, or *No*. Multiple facets of cognitive problems were assessed, with each item introduced by a specific cognitive domain label, followed by a descriptive statement. Examples include “Memory: I experience difficulties remembering important information, such as dates, names, or past events”, and “Language Skills: I struggle to find the right words during conversations or have trouble understanding what others are saying.”. The last item provided participants with the opportunity to report cognitive concerns not previously covered - “Other Cognitive Concerns: I have other cognitive issues that I

have noticed, namely:". An additional question was addressed regarding engagement in cognitive abilities training, in which participants rated their response on a scale from 1 to 100, with 1 indicating *Not at all* and 100 indicating *Yes a lot*.

Neurofeedback Educational Information

After answering the questions, participants received some information on neurofeedback, how it works and what neurofeedback sessions look like. This also included some images that further explained this process. Participants also received some basic information on the goals of the neurofeedback learning companion. They were also shown a short video of the setup of neurofeedback, including the learning companion. When they had seen all this information, they had to do a short quiz to make sure they had a good enough understanding of neurofeedback and the learning companion to continue the study. After the quiz, participants had to answer a few questions on whether they felt like they understood what neurofeedback and the learning companion are.

Questionnaire Regarding Neurofeedback

Participants were asked about whether they had heard about neurofeedback before participating in this study, and if they had any previous experience with it. Finally, they were asked questions on a 0-100 scale on their thoughts about neurofeedback, with 0 being *completely disagree*, and 100 being *completely agree*. They were asked whether they thought neurofeedback is a treatment, if they thought it could work supplementary to medication and if they could imagine it as a treatment method.

Questionnaire Assessing the Design Preferences of the Tangible Robot-like Neurofeedback Companion

Participants were asked to indicate whether they had ever been in contact with a learning companion before, and if so, what kind of companion it was. They were asked to rank four different companions based on the trustworthiness of their shape based on pictures included in the questionnaire. Moreover, participants were asked to indicate how trustworthy they found four possible names of the companion. Trustworthiness was indicated on a scale from 0 (*not trustworthy*) to 100 (*maximally trustworthy*). With trustworthiness we mean that participants would accept the learning companion's feedback and apply it during the neurofeedback sessions.

The type of color and the number of colors a trustworthy companion should have were evaluated as well. Participants were able to choose between four different options each. Additionally, participants were asked to assess four voice samples and indicate which voice a trustworthy companion should have. The perceived fit of the voice was indicated on a scale from 0 (*not fitting at all*) to 100 (*maximally fitting*).

The behavior of the companion was evaluated as well. Participants were asked when they would like to receive feedback from the companion during the neurofeedback sessions (e.g. only when they succeed, only when they fail, or both) and whether they thought that a companion could distract them from neurofeedback. This last point was assessed using a scale from 0 (*completely disagree*) to 100 (*completely agree*).

Acceptability Questionnaire

Acceptability was measured using eleven selected and adapted questions from the Acceptability Model for BCIs designed by Grevet et al. (2023). Within this variable, three key components were assessed using three questions for each: perceived ease of use (e.g. "I think practicing neurofeedback with the neurofeedback companion would be easy."), perceived usefulness (e.g. "I think that the neurofeedback companion will make the neurofeedback training

more pleasant."), and behavioral intention (e.g. "Assuming I had access to a neurofeedback companion during my neurofeedback training, I would use it.").

In addition to the core domains of acceptability, the questionnaire also included one item each for both technology-related pleasure and confidence in using new technologies, suggesting the importance of psychological factors in acceptability (Grevet et al., 2023). All eleven selected questions were in the form of a visual analogue scale ranging from 0 (*totally disagree*) to 100 (*totally agree*).

Grevet et al. 's (2023) Acceptability Model has great internal consistency as demonstrated by the Cronbach's α scores ranging from .83 to .97 for the subdomains of acceptability. Regarding attitudes on technology, while the domain of pleasure shows a high level of internal consistency (α = .83), confidence in using new technologies is rated more poorly (α = .57).

Personality

Personality was assessed using the Big Five Inventory (John et al., 1991), which consists of 44 items rated on a 5-point Likert scale ranging from *Disagree strongly* to *Agree strongly*. The questionnaire measures five personality domains, namely openness to experience, conscientiousness, agreeableness, extraversion, and neuroticism. Examples include "I see myself as someone who is generally trusting" and "I see myself as someone who worries a lot". The instrument demonstrates a good internal consistency, with Cronbach's α values ranging from .79 (Agreeableness) to .88 (Extraversion), and an average α of .83 across all domains (John & Srivastava, 1999) .

Statistical Analysis

H1: Differences Between ADHD and Neurotypical Individuals Regarding Perceived Usefulness

For the first hypothesis, an independent samples t-test was performed comparing individuals with ADHD to neurotypical individuals on PERCEIVED USEFULNESS. Those who are suspecting they have AD(H)D are included in the sample. The neurotypical group was closely matched to have the same number of people as the ADHD group. This matching was done based on age and gender. The independent variable is ADHD (two levels: ADHD, neurotypical) and the dependent variable is PERCEIVED USEFULNESS.

H2: Differences Between ADHD and Neurotypical Individuals and Work Status Regarding Perceived Ease of Use

For the second hypothesis, a two-way ANOVA was performed comparing individuals with ADHD to neurotypical individuals and thereby looking at work status on PERCEIVED EASE OF USE. The independent variables are ADHD (two levels: ADHD, neurotypical) and WORK STATUS (five levels: full-time, part-time, unemployed, student, other), and the dependent variable is PERCEIVED EASE OF USE. The neurotypical individuals were matched to the ADHD group based on age, gender, and work status.

H3: Differences Between ADHD and Neurotypical Individuals and Work Status Regarding Behavioural Intention

For the third hypothesis, a two-way ANOVA was performed comparing individuals with ADHD to neurotypical individuals and thereby looking at work status on BEHAVIOURAL INTENTION. The independent variables are ADHD (two levels: ADHD, neurotypical) and WORK STATUS (five levels, full-time, part-time, unemployed, student, other), and the dependent variable is BEHAVIOURAL INTENTION. The neurotypical individuals were matched to the ADHD group based on age, gender, and work status.

A Bonferroni correction to compare groups to avoid chance inflation will be done in case of a significant F-statistic ($F < 0.05$).

Assumptions

The assumptions that need to be met for the t-test and the two-way ANOVAs are independent observations, normality, and homoscedasticity. Independent observations are met if every participant only participated once and has been placed in one singular group. Normality will be checked with the Shapiro-Wilk test and will be rejected if $p < .05$. If the data is not normally distributed, the non-parametric Kruskal-Wallis H test can be used. Homoscedasticity will be checked with a Levene's test, a non-significant result ($p > 0.05$) will lead to the assumption being met. If there is no equal variance of the groups, the Welch test will be used.

Interpretation of Acceptability Values

In this study a score of 60 or higher on acceptability (this includes all three domains: perceived usefulness, perceived ease of use, and behavioural intention) is seen as the threshold for people to see the tangible robot-like neurofeedback companion as acceptable. Where a score of 50 is seen as neutral, this study aims for an acceptability score that is higher than that to ensure people really want to make use of a new technology. This threshold is not based on any previous literature.

There was no power analysis conducted before the study, but the final sample size (N = 102) is high enough for achieving adequate power in within-subjects designs with medium effect sizes (Faul et al., 2007). Faul et al. (2007) also mention that for an ANOVA there have to be at least 28 participants to detect medium effects ($F = .25$) with alpha = .05 and power = .80. The sample in this study exceeds this threshold and therefore shows sufficient sensitivity to detect hypothesized effects.

All statistical analyses were performed using IBM SPSS Statistics 28 (2024).

Data Preparation

The initial response to the questionnaire was 854 participants, of whom 222 did not finish one or more questions in the questionnaire and were therefore excluded. This leads to a total of 632 participants. After this, the ADHD group got defined and there were 51 participants in this group (*Note*$_1$: people reporting ADD and suspected AD(H)D were also part of the ADHD group, therefore an official diagnosis was not requested; *Note*$_2$: participants with comorbid disorders where ADHD is one of them were allowed). Then a neurotypical group of participants got matched (n = 51) closely to the ADHD group based on age, gender, and work status. Matching was done by randomly selecting 51 neurotypical individuals with (roughly) the same age, gender, and work status in the SPSS dataset. A separate variable was made for ADHD (0 = neurotypical, 1 = ADHD). This leads to a total of 102 participants in the final sample of this study.

For work status a separate variable was made to get each individual into one of the groups, WORK STATUS (0 = unemployed, 1 = full-time employed, 2 = part-time employed, 3 = student, and 4 = other).

The three acceptability domains each included three questions, and these were combined into composite scores for each domain: PERCEIVED USEFULNESS, PERCEIVED EASE OF USE, and BEHAVIOURAL INTENTION.

Results

The mean age of the final sample was 24.16 (SD = 9.26), with 70.59% of the sample being women and 46.08% working part-time. The mean average for acceptability was 65.19 (SD = 16.75), with PERCEIVED USEFULNESS (M = 66.31, SD = 17.23), PERCEIVED EASE OF USE (M = 63.86, SD = 16.43), and BEHAVIOURAL INTENTION (M = 65.38, SD = 21.00). The demographic characteristics of the final sample (n = 102) are displayed below in Table 1.

The demographic characteristics of the full sample (N = 632) are displayed in the Appendix (Table 2).

Table 1

Demographic characteristics for the final sample, ADHD group and matched neurotypical group

	ADHD group (n = 51)	Neurotypical group (n = 51)
Age, *M* (SD)	24.25 (9.23)	24.06 (9.29)
Gender, n (%)		
Women (1)	37 (72.55%)	35 (68.63%)
Men (2)	10 (19.61%)	12 (23.53%)
Other (0)	4 (7.84%)	4 (7.84%)
Psychiatric/Neurological Disorder		
Total, n (%)[1]	51 (100.00%)	-
Autism	8 (15.69%)	-
ADHD	51 (100%)	-
Depression	6 (11.76%)	-
Anxiety	8 (15.69%)	-
Other*	11 (21.57%)	-
Work status		
Full-time (1), n (%)	5 (9.80%)	5 (9.80%)
Part-time (2), n (%)	24 (47.06%)	23 (45.10%)
Unemployed (0), n (%)	1 (1.96%)	0 (0.00%)
Student (3), n (%)	20 (39.22%)	22 (43.14%)
Other** (4), n (%)	1 (1.96%)	1 (1.96%)

Acceptability, *M* (SD)	68.06 (16.70)	62.31 (16.80)
PU[2], *M* (SD)	68.64 (17.93)	63.97 (16.52)
PEOU[2], *M* (SD)	65.35 (16.46)	62.36 (16.40)
BI[2], *M* (SD)	70.18 (21.16)	60.58 (20.83)

Note[1]: number may be higher than the total of people who reported psychiatric/neurological disorders, because of comorbidity

Note[2]: the acceptability domains PERCEIVED USEFULNESS, PERCEIVED EASE OF USE, and BEHAVIOURAL INTENTION are taken as composite scores of each three questions about the domains

*This category includes: PTSS, tinnitus, MS, restless leg syndrome, OCD, acquired brain injury, neuropathy, migraines, memory loss, somatic syndrome, epilepsy, dyslexia, anorexia nervosa, alcohol use disorder, personality disorders, and 'other/don't want to specify'

**This category includes: not able to work, self-employed, housewife/househusband, volunteer, retired, and 'I prefer not to say'

Hypothesis 1: People with ADHD Perceive a Tangible Robot-like Neurofeedback Companion as More Useful than Neurotypical Individuals

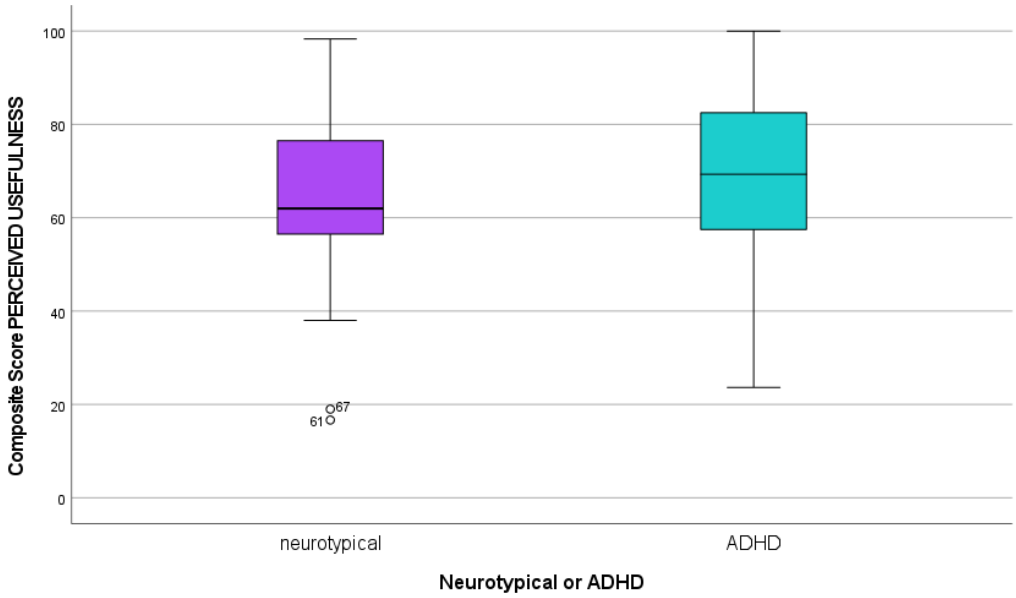
Before analysing the data, the assumptions for an independent samples t-test were checked and none of them were violated. Normality was not violated, because the Shapiro-Wilk test indicated that PERCEIVED USEFULNESS was normally distributed, $W(102) = .980$, $p = .136$ (see Table 3 and Figure 4 in Appendix). Homoscedasticity was not violated, because the Levene's test did not show significance ($p = .436$) (see Table 4 in Appendix).

An independent samples t-test was performed comparing 51 people with ADHD and 51 neurotypical individuals to test the first hypothesis. There was no significant difference between

the ADHD group (M = 68.64, SD = 17.93) and the neurotypical group (M = 63.97, SD = 16.52) on PERCEIVED USEFULNESS; t(100) = -1.37, p = .09, d = -0.27 (see Table 5 and Table 6 in Appendix). Figure 1 shows the boxplots for the ADHD and neurotypical group on PERCEIVED USEFULNESS. To conclude, the first hypothesis cannot be supported, but there is a statistical trend (p = .09), suggesting a potential difference between the ADHD and the neurotypical group on PERCEIVED USEFULNESS, where individuals with ADHD score higher on PERCEIVED USEFULNESS than neurotypical individuals.

Figure 1

Boxplots of Perceived Usefulness for the ADHD Group and the Neurotypical Group



Hypothesis 2: Having ADHD is Associated with Higher Perceived Ease of Use, Being Full-time Employed is Associated with Lower Perceived Ease of Use, and There is an Interaction Effect Between Work Status and ADHD

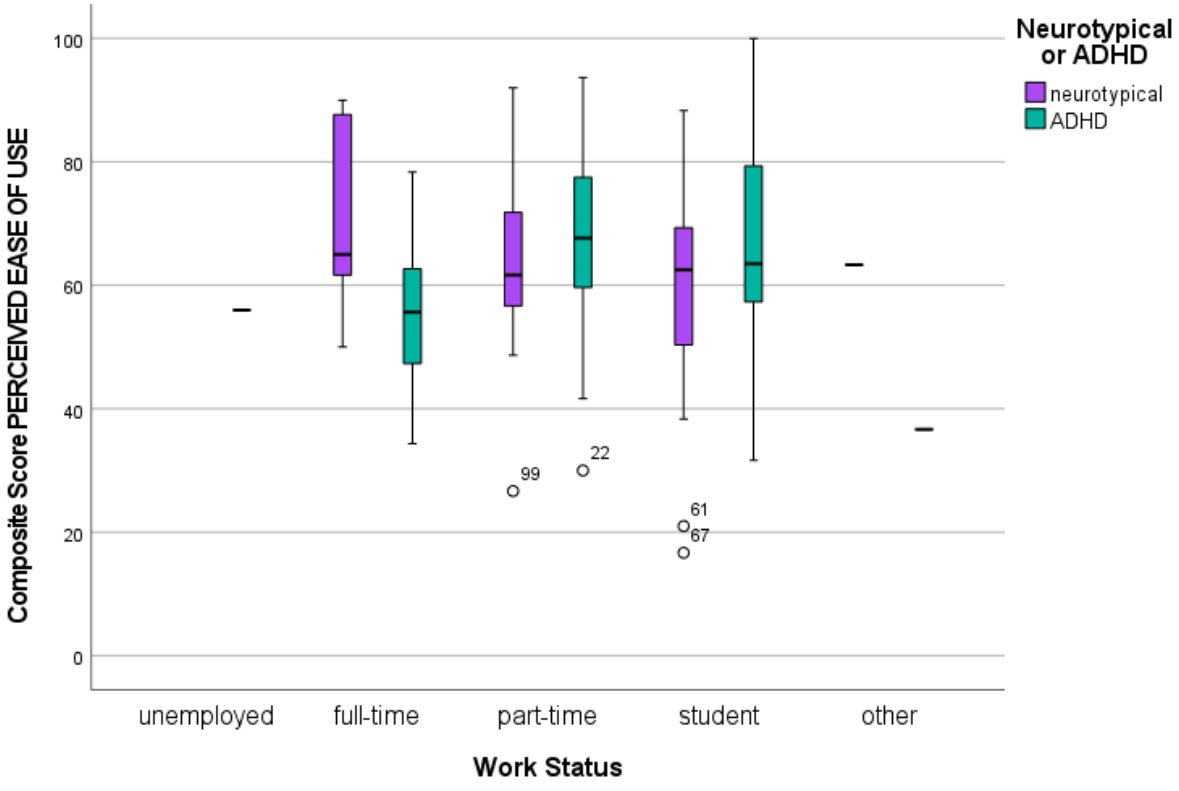
Before analysing the data, the assumptions for the two-way ANOVA were checked and none of them were violated. Normality was not violated for PERCEIVED EASE OF USE, because the Shapiro-Wilk test indicated that it was normally distributed, W(102) = .982, p = .178

(see Table 7 and Figure 5 in Appendix). The assumption of homoscedasticity was not violated, because the Levene's test indicated $F(5, 93) = 0.304$, $p = .909$ (see Table 8 in Appendix).

The results showed no significant main effect for ADHD, $F(1, 93) = 1.31$, $p = .255$. The results also showed no significant main effect for WORK STATUS, $F(4, 93) = 0.64$, $p = .639$ (see Table 9 in Appendix). The interaction effect between ADHD and WORK STATUS was not significant, $F(3,93) = 2.12$, $p = .101$ (see Figure 6 in Appendix). Figure 2 shows the boxplots of PERCEIVED EASE OF USE for the ADHD and the neurotypical group combined with work status. To conclude, the second hypothesis cannot be supported.

Figure 2

Boxplots of Perceived Ease of Use for the ADHD Group and the Neurotypical Group Combined with Work Status



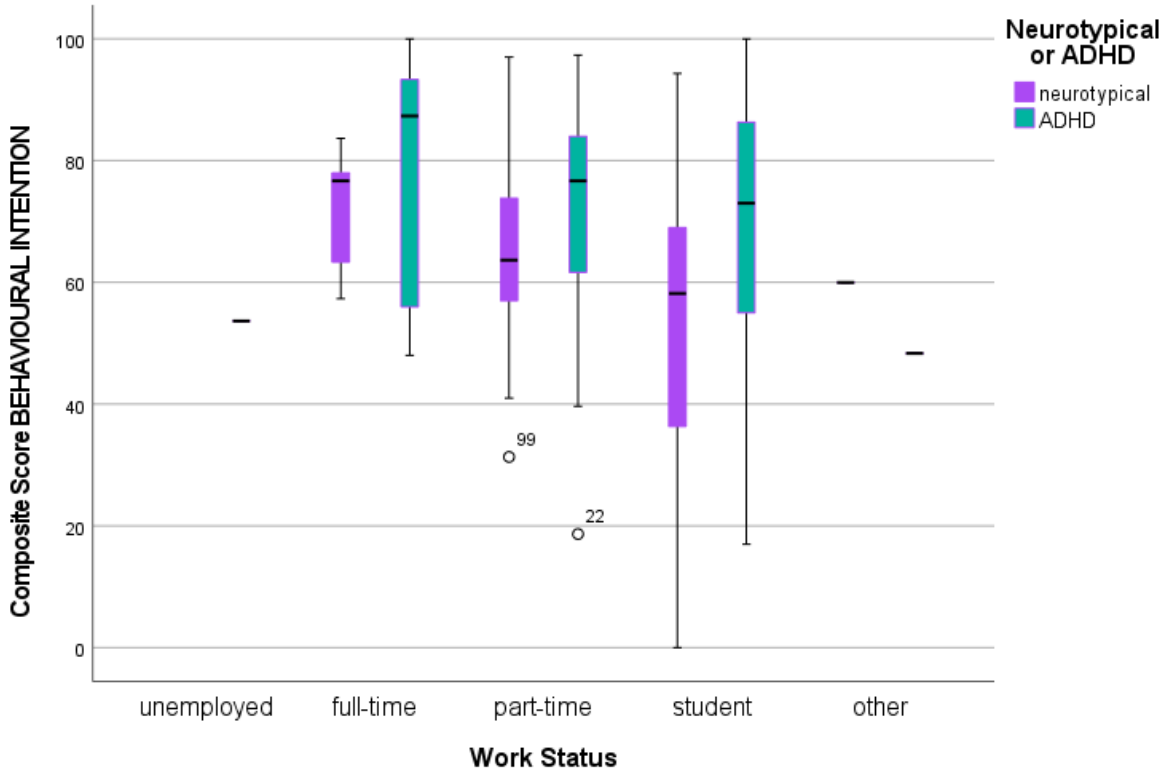
Hypothesis 3: Having ADHD is Associated with Higher Behavioural Intention, Being Full-time Employed is Associated with Lower Behavioural Intention, and There is an Interaction Effect Between Work Status and ADHD.

Before analysing the data, the assumptions for the two-way ANOVA were checked and only normality was violated. The assumption of normality was violated for BEHAVIOURAL INTENTION, because the Shapiro-Wilk test indicated that it was not normally distributed, $W(102) = .961$, $p = .004$ (see Table 10 and Figure 7 in Appendix). Although the Shapiro-Wilk test indicated the normality assumption was violated, the sample size (n = 51 per group) is large enough and an ANOVA is robust to moderate violations of normality. Homoscedasticity is met, because the Levene's test indicated $F(5, 93) = 1.570$, $p = .176$ (see Table 11 in Appendix).

The results showed no significant main effect for ADHD, $F(1, 93) = 0.21$, $p = .650$. The results also showed no significant main effect for WORK STATUS, $F(4, 93) = 1.87$, $p = .122$ (see Table 12 in Appendix). The interaction effect between ADHD and WORK STATUS was not significant, $F(3, 93) = 0.52$, $p = .669$ (see Figure 8 in Appendix). Figure 3 shows the boxplots of BEHAVIOURAL INTENTION for the ADHD and the neurotypical group combined with work status. To conclude, the third hypothesis cannot be supported.

Figure 3

Boxplots of Behavioural Intention for the ADHD Group and the Neurotypical Group Combined with Work Status



Discussion

The aim of this online questionnaire study was to look for differences between individuals with ADHD and neurotypical individuals on perceived usefulness, as well as the influence of different work statuses and ADHD on two separate acceptability domains (perceived ease of use and behavioural intention). The reason behind investigating this is to identify if a tangible robot-like neurofeedback companion will be accepted by individuals to possibly enhance neurofeedback. Through a feasibility study focusing on acceptability, this study was set to create an overview of people their self-reported acceptability score towards this new technology. A total of 102 participants entered the main analysis of this study. In the following sections the results will be discussed, strengths and limitations will be given, as well as implications and practical recommendations, followed by future directions, and ending with conclusions of this study.

Discussion of Results

The results related to the first hypothesis show that having ADHD does not indicate that this group will consider a tangible robot-like neurofeedback companion as more useful than neurotypical individuals. This outcome is not consistent with the first hypothesis. It could be the case that the initial acceptability (perceived usefulness) of a tangible robot-like neurofeedback companion is the same for people with or without ADHD, but with actual interaction with a tangible robot-like neurofeedback companion there will be differences. In the Technology Acceptance Model (TAM) from Davis (1989) it states that people their cognitive problems (e.g. ADHD) should influence perceived usefulness of a new technology. This means that people with cognitive problems like ADHD should score higher on perceived usefulness than neurotypical individuals, because they can benefit the most from the tangible robot-like neurofeedback companion. This contradicts the outcome of this study.

The results related to the second hypothesis show that having ADHD does not indicate a higher score on perceived ease of use than neurotypical individuals. It also shows that people working full-time jobs do not score lower on perceived ease of use than people with other work statuses (part-time, student, unemployed, other). This contradicts the findings of Mawjee et al. (2019), where they state that people with full-time jobs drop-out more often than people who do not have full-time jobs. People working full-time jobs also reported higher stress due to the neurofeedback training being very demanding next to their job. In this current study, people working full-time do not respond significantly different than people working part-time for example. This could be due to the participants not truly taking part in the neurofeedback training and therefore they cannot accurately imagine what the added value of a tangible robot-like neurofeedback companion could be in the neurofeedback setting. Additionally, the influence of

work status on perceived ease of use was not higher in the ADHD group compared to the neurotypical group. Having ADHD and a full-time job could be factors for underperforming at the workplace, as well as reporting high stress levels and time constraints regarding neurofeedback training (Fuermaier et al., 2021; Mawjee et al., 2019). This could be a reason why people with ADHD do not significantly score higher on perceived ease of use, even though they have a higher 'need' for a cognitive intervention than neurotypical individuals.

The results related to the third hypothesis show that having ADHD does not indicate that this group will score higher on behavioural intention than neurotypical individuals. It also shows that people working full-time jobs do not score lower on behavioural intention than people with other work statuses (part-time, student, unemployed, other). Additionally, in the results for the third hypothesis, the influence of work status on behavioural intention was not higher in the ADHD group compared to the neurotypical group. Similar possible explanation could be given as those for the second hypothesis in the paragraph above.

Strengths and Limitations

A strength of this study was the large and international sample size. The online questionnaire was available in multiple languages (English, Dutch, French, Spanish, and German) and therefore it allowed this study to reach a diverse group of individuals with different backgrounds. Next to that, this study is also one of the first studies asking the general public for their views on a tangible robot-like neurofeedback companion, a relatively new concept in research. This serves as a stepping stone towards larger studies and represents an innovative approach.

In contrast, there are also several limitations of this study. Sekhon et al. (2017) reported that acceptability is necessary for the effectiveness of an intervention, but there is not enough

information on what an appropriate acceptability score is. In this study the threshold for a ‘good’ acceptability score was 60, but this was not based on any literature. In future research there should be a question included in the questionnaire asking participants what they perceive as a ‘good’ acceptability score. This might give more insight and meaning to the results on overall acceptability and the three separate acceptability domains. Subsequently, most participants were women and relatively young (18-23 years), and also most of the participants were university students. The questionnaire also took longer than stated for some participants, this could be a reason for people to drop out of the study or rush through questions at the end of the questionnaire. Lastly, there are no set guidelines on acceptability as of now, which makes it difficult to set a threshold for something to be found ‘accepted’.

Implications and Practical Recommendations

The neurotypical group reported the lowest acceptability score on behavioural intention. In contrast, behavioural intention got the highest scores from the ADHD group and therefore an intervention in that domains could be more beneficial to them. They report that they have the behavioural intention to make use of a tangible robot-like neurofeedback companion, but putting intention to behaviour is difficult for a lot of people (Feil et al., 2023). This intention-behaviour gap is a well-known phenomenon and persistent issue across numerous new interventions, regardless of the target population (Bassett, 2015; Conner & Norman, 2022; Khan et al., 2024b). To get insight in this regarding behavioural intention, there needs to be a study about people with ADHD who report high scores on behavioural intention and have a follow-up study with that group and a neurotypical comparison group to see if they will or will not drop out of the actual neurofeedback training sessions, and if this has something to do with having ADHD or not.

A first step has been taken to conduct this study. This is important for the field of mental health research in general, but also the technological field. This study provides a foundation for further assessment of the three acceptability domains (perceived usefulness, perceived ease of use, and behavioural intention) and look at the results. If in further research the study included a wider variety in age and has bigger groups in the work status variable to ensure that the groups are being compared with equal group numbers, this may potentially lead to a significant outcome.

Future Research

By further examining work status as a potential influential factor in the acceptability towards a tangible robot-like neurofeedback companion, new interventions can be developed that are even more personalized and might suit individuals with every type of work status. This can also help find ways to improve neurofeedback in general. Next to that, if people score high on acceptability (full-time employed people), but another study (Mawjee et al., 2019) shows that these people drop-out the most, what could be the cause of this? There needs to be more research on the gap between initial acceptability and eventually dropping out of the study. Additionally, in this current study, people working full-time do not respond significantly different than people with other work statuses. This could be due to the study being an acceptability study and the participants not truly undergoing neurofeedback training sessions. In future research, the influence of work status on acceptability towards a tangible robot-like neurofeedback companion needs to be assessed to see if the results of this study will withstand when people truly take the neurofeedback training sessions.

Moreover, neurofeedback training can be used to enhance cognitive function and clinical symptoms. The outcome that the ADHD group scores above 60 on all three domains of

acceptability is therefore important, because this (sub)clinical group might benefit most from neurofeedback (Cai et al., 2021; Enriquez-Geppert et al., 2014; Smit et al., 2023). The results show a trend, with people in the ADHD group reporting higher scores on perceived usefulness than the neurotypical group. There needs to be more research on ADHD groups, but also on groups with other psychological disorders, to see if this is a target group for neurofeedback with a tangible robot-like neurofeedback companion or not. These individuals might benefit the most, therefore their opinion is highly valued.

Conclusion

This feasibility-acceptability study was conducted to get a view on the current opinion of the general public towards a tangible robot-like neurofeedback companion as a new technology that can be used in combination with neurofeedback training sessions. The mean score (M = 65.19) of the overall acceptability on the tangible robot-like neurofeedback companion seems promising for the future within the field of neurofeedback training. The use of a tangible robot-like neurofeedback companion could improve the outcomes of neurofeedback training and could be used more broadly in healthcare, because it is personalized and adapted to the individual. Hopefully, the use of a tangible robot-like neurofeedback companion could also decrease the number of non-responders to neurofeedback. This should be tested in future research, as well as focusing on bigger and more equal groups regarding work status and ADHD.

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Appendix

Table 2

Demographics for the Full Sample

	Full sample (N = 632)
Age, *M* (SD)	27.48 (14.42)
Gender, n (%)	
Women (1)	475 (75.20%)
Men (2)	144 (22.80%)
Other (0)	13 (2.00%)
Psychiatric/Neurological Disorder	
Total, n (%)[1]	135 (21.36%)
Autism	23 (3.64%)
ADHD	51 (8.07%)
Depression	33 (5.22%)
Anxiety	33 (5.22%)
Other*	52 (8.23%)
Work status	
Full-time (1), n (%)	96 (15.20%)
Part-time (2), n (%)	180 (28.50%)
Unemployed (0), n (%)	10 (1.60%)
Student (3), n (%)	307 (48.6%)
Other** (4), n (%)	39 (6.20%)
Acceptability, *M* (SD)	67.09 (17.52)

PU[2], *M* (SD)	67.76 (18.65)
PEOU[2], *M* (SD)	66.43 (17.14)
BI[2], *M* (SD)	67.06 (21.07)

Note[1]: number may be higher than the total of people who reported psychiatric/neurological disorders, because of comorbidity

Note[2]: the acceptability domains PERCEIVED USEFULNESS, PERCEIVED EASE OF USE, and BEHAVIOURAL INTENTION are taken as composite scores of each three questions about the domains

*This category includes: PTSS, tinnitus, MS, restless leg syndrome, OCD, acquired brain injury, neuropathy, migraines, memory loss, somatic syndrome, epilepsy, dyslexia, anorexia nervosa, alcohol use disorder, personality disorders, and 'other/don't want to specify'

**This category includes: not able to work, self-employed, housewife/househusband, volunteer, retired, and 'I prefer not to say'

Table 3

Tests of Normality for Perceived Usefulness

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Composite score perceived usefulness	.060	102	.200*	.980	102	.136

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Figure 4

Q-Q Plot Perceived Usefulness

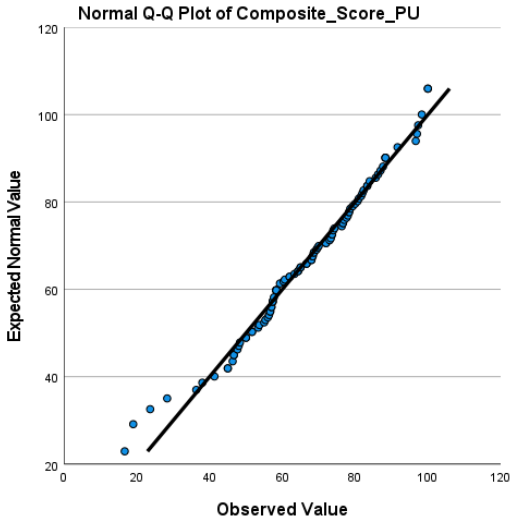


Table 4

Test of Homogeneity of Variances for the Composite Score of Perceived Usefulness

	Levene's statistic	Df1	Df2	Sig.
Based on mean	.612	1	100	.436

Table 5

Independent Samples T-test for Composite Score of Perceived Usefulness

							95% Confidence Interval of the Difference	
	t	df	One-Sided p	Two-Sided p	Mean difference	Std. Error Difference	Lower	Upper

Equal variances assumed	-1.367	100	.087	.175	-4.667	3.414	-11.440	2.107

Table 6

Independent Samples Effect Sizes for Composite Score of Perceived Usefulness

			95% Confidence Interval	
	Standardizer[a]	Point Estimate	Lower	Upper
Cohen's d	17.240	-.271	-.660	.120
Hedges' correction	17.371	-.269	-.655	.119
Glass's delta	17.930	-.260	-.650	.132

a. The denominator used in estimating the effect sizes.

Cohen's d uses the pooled standard deviation.

Hedges' correction uses the pooled standard deviation, plus a correction factor.

Glass's delta uses the sample standard deviation of the control group.

Table 7

Tests of Normality for Perceived Ease of Use

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.

Composite score perceived ease of use	.064	102	.200*	.982	102	.178

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Figure 5

Q-Q plot Perceived Ease of Use

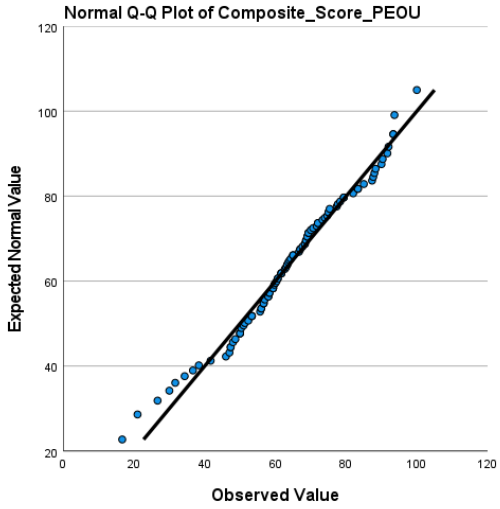


Table 8

Levene's Test of Equality of Error Variances for the Composite Score of Perceived Ease of Use

	Levene's statistic	Df1	Df2	Sig.
Based on mean	.304	5	93	.909

Table 9

Tests of Between-Subjects Effects for the Composite Score of Perceived Ease of Use

	Type 3 Sum of Squares	df	Mean Square	F	Sig.
Corrected model	2675.944[a]	8	334.493	1.267	.270
Intercept	69051.263	1	69051.263	261.606	<.001
Neurotypical0_ADHD1	345.957	1	345.957	1.311	.255
Work_Status	670.821	4	167.705	.635	.639
Neurotypical0_ADHD1 * Work_Status	1689.622	3	563.207	2.134	.101
Error	24547.517	93	263.952		
Total	443097.667	102			
Corrected total	27223.461	101			

a.R Squared = .098 (Adjusted R Squared = .021)

Figure 6

Interaction Effect of Perceived Ease Of Use for the ADHD Group and the Neurotypical Group Together with Work Status

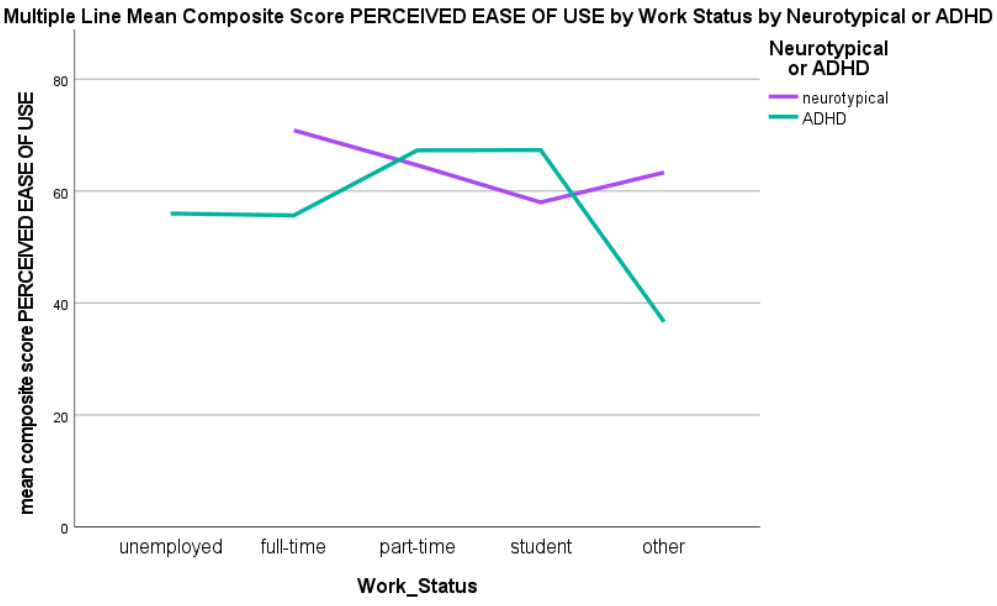


Table 10

Tests of Normality for Behavioural Intention

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Composite score behavioural intention	.084	102	.071	.961	102	.004

a. Lilliefors Significance Correction

Figure 7

Q-Q plot Behavioural Intention

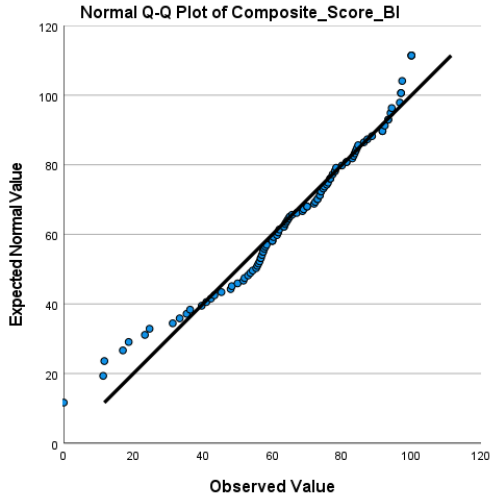


Table 11

Levene's Test of Equality of Error Variances for the Composite Score of Behavioural Intention

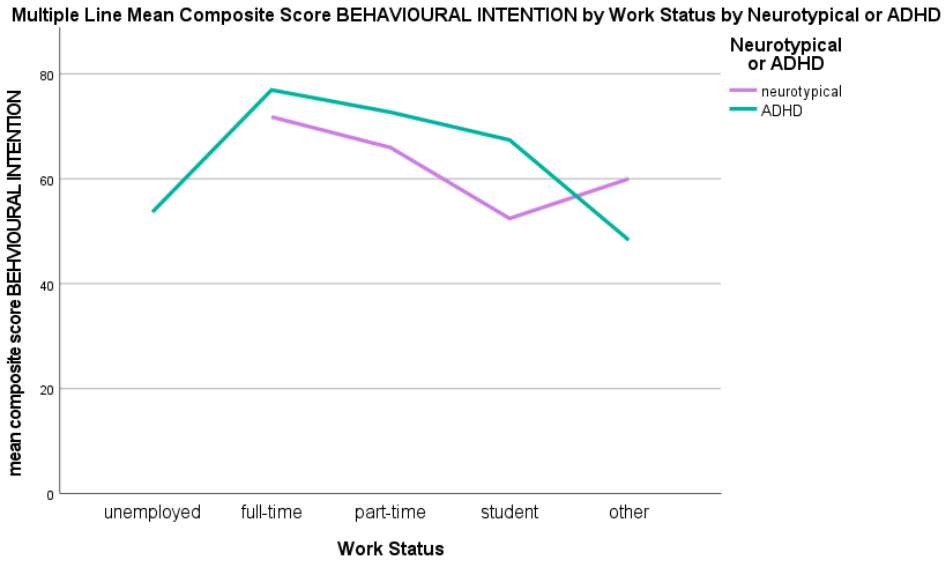
	Levene's statistic	Df1	Df2	Sig.
Based on mean	1.570	5	93	.176

Table 12

Tests of Between-Subjects Effects for the Composite Score of Behavioural Intention

	Type 3 Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	6387.598[a]	8	798.450	1.854	.077
Intercept	74501.432	1	74501.432	173.010	<.001
Neurotypical0_ADHD1	89.120	1	89.120	.207	.650
Work_Status	3218.930	4	804.732	1.869	.122
Neurotypical0_ADHD1 * Work_Status	673.243	3	224.414	.521	.669
Error	40047.602	93	439.619		
Total	482470.111	102			
Corrected Total	46435.199	101			

a.R Squared = .138 (Adjusted R Squared = .063)

Figure 8

Interaction Effect of Behavioural Intention for the ADHD Group and the Neurotypical Group Together with Work Status