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DISCUSSION

Assessing the Attitude Towards Artificial Intelligence: Introduction of a Short Measure in German, Chinese, and English Language

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Abstract

In the context of (digital) human–machine interaction, people are increasingly dealing with artificial intelligence in everyday life. Through this, we observe humans who embrace technological advances with a positive attitude. Others, however, are particularly sceptical and claim to foresee substantial problems arising from such uses of technology. The aim of the present study was to introduce a short measure to assess the Attitude Towards Artificial Intelligence (ATAI scale) in the German, Chinese, and English languages. Participants from Germany (N = 461; 345 females), China (N = 413; 145 females), and the UK (N = 84; 65 females) completed the ATAI scale, for which the factorial structure was tested and compared between the samples. Participants from Germany and China were additionally asked about their willingness to interact with/use self-driving cars, Siri, Alexa, the social robot Pepper, and the humanoid robot Erica, which are representatives of popular artificial intelligence products. The results showed that the five-item ATAI scale comprises two negatively associated factors assessing (1) acceptance and (2) fear of artificial intelligence. The factor structure was found to be similar across the German, Chinese, and UK samples. Additionally, the ATAI scale was validated, as the items on the willingness to use specific artificial intelligence products were positively associated with the ATAI Acceptance scale and negatively with the ATAI Fear scale, in both the German and Chinese samples. In conclusion we introduce a short, reliable, and valid measure on the attitude towards artificial intelligence in German, Chinese, and English language.

Keywords Artificial Intelligence · ATAI · German · Chinese · English · ATAI scale · Attitude Towards Artificial Intelligence

1 Introduction

Recent years have seen tremendous developments in products of technologies within artificial intelligence (AI). While some people appear to be open towards the rise of AI products in everyday life and appreciate the advantages, others seem sceptical and concerned about the emerging impact of AI products. Introducing a short and valid measure to assess individual differences in such attitudes was the aim of the present study to enable future research on human–AI interaction.

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The term AI refers to a technology where software and/or machines are able to mimic (certain aspects of) human intelligence (for a more elaborate discussion see Fetzer [1]). As such, AI is a broad discipline encompassing a wide range of scientific disciplines such as computer science, engineering, biology, neuroscience, and psychology. During the last years, products in the field of AI are, undoubtedly, getting "smarter" in terms of the machine learning algorithms used. Recent examples are Google's AlphaGo (an AI computer program that plays the game "Go") defeat over a Chinese Go Master [2] or Google's AutoML (Automatic Machine Learning; invented to teach AI software to build other AIs) creating an AI, which is smarter than the previous man-made one [3]. In line with this progress, recent years have seen dramatic developments in the construction of self-driving cars, a forthcoming billion-dollar industry. Here, AI will support humans, which will no longer need to pay attention to the roads while travelling. An example for such an ongoing project is the self-driving car of Google [4]. Further to this, several products relying on AI have already been launched for use in everyday life with considerable media attention in the past few years. Prominent examples are Siri developed by Apple, currently included in Apple devices, such as computers and smartphones (https://www.apple.com/siri/), and Alexa developed by Amazon (https://developer.amazon.com/alexa) [5]. Siri represents a digital service humans can give voice commands to in order to access information, such as the weather forecast and information on directions to navigate to a specified destination. Comparably, Amazon launched a service called Alexa, an AI product that — like Siri — reacts to human voice commands. One can instruct Alexa to play a song, or to add items to a shopping list, to name a few examples. Similarly, Google relies on AI for its voice assistants, as used in Google Home (Smart Home Assistant) and installed in current Android Smartphones (https://assistant.google.com/intl/en_uk/). Furthermore, AI research has led to the development of robots, including humanoid robots [6], which have the ability to be companions to humans and are, therefore, deemed as social robots. Pepper, for example, is a robot already used within over 2,000 companies around the world to interact with visitors and customers. It was developed by the company Aldebaran and is able to recognize faces and partake in conversations with humans (https://www.softbankrobotics.com/emea/en/pepper). Further examples for AI-based humanoid robots are those created by Hiroshi Ishiguro and his colleagues. Among others, the team built a humanoid female robot named Erica, which actually looks human-like and is declared "an autonomous conversational android with an unprecedented level of human-likeness and expressivity, as well as advanced multimodal sensing capabilities" [7], p 22. Another example would be Atlas®, which was created by Boston Dynamics [8]. It is described as "the most dynamic humanoid robot" [8] and its aim is to be deployed for rescue work in situations, which humans would not survive [8, 9].

The rise of AI in daily life bears several opportunities and future promises, including safer driving or improved medical care. For example, one is able to ask the AI assistants for help by voice command. This enables people to start a navigation system while already driving, making it unnecessary to stop the car to manually set it up, or even manually setting it up while driving. Also, AI is increasingly used in the medical sector. For instance, AI is used for robots to assist elderly patients or surgeons [10]. Also Pepper serves in hospitals in Belgium as a receptionist [11]. However, alongside such positive outcomes, naturally, the progress in AI research and AI development has several disadvantageous consequences and potential perils. As with every technological progress, machines are progressively being used to replace humans at work, which causes tremendous numbers of employment dismissals every year. In one study it was estimated that around 38% of the jobs, which are currently carried out by humans, will be cut due to automation in the USA by the year 2030 [12]. Needless to say, the "smarter" machines get (i.e., the more effective the AI gets), the more jobs can be carried out by these machines. In turn, these jobs will be taken from humans by the machines. However, some also argue that AI can create new job opportunities [13]. Moreover, concerns with respect to data privacy are increasingly debated with respect to the increasing engagement of AI products in daily life. Prominent examples are the big tech companies recording, listening to, and analysing private conversations of people via their AI products [14].

In line with the existing advantages, as well as the disadvantages, of AI products, it does not seem surprising that some people have a very open-minded opinion and accept the emergence of AI products and acknowledge their advantages for humans. In contrast to this, others seem to be ambivalent or even sceptical and fearful regarding the rise of AI products (LINK Institut (2018) as cited in Statista [15]). This leads as far as to prominent influencers in the field, such as Stephen Hawking and Elon Musk, publicly stating that progress in AI research has the potential to end humankind [16, 17].

Given the varying attitudes towards AI, the main aim of this study is to develop and introduce a short, reliable, and valid measure to assess individual differences in the attitude towards AI. As AI is a worldwide phenomenon, it is important to present and test such a measure in various languages and across cultures. Therefore, German, Chinese, and English versions of the self-report measure will be subject to this study. The factorial structure of this measure, including invariance analyses across samples from Germany, China, and the UK, will be investigated. Moreover, potential gender differences in this measure will be examined. Thereby, it is tested whether the previously reported effects of more positive attitudes in males found with regard to technology acceptance, a field closely related to AI, extend to the current measure [18, 19]. Lastly, the associations of the newly developed measure with items on the willingness to use several specific AI products (self-driving cars, Siri, Alexa, Pepper, and Erica) in Germany and China will be investigated for validation. In detail, we expect a more positive attitude towards AI to be associated with a higher willingness to use such AI products. More negative attitudes should be associated with lower willingness to use such AI products.

2 Materials and Methods

2.1 Samples

The initial dataset of the German sample included N = 465 participants. After exclusion of data of participants who took part in the study twice (N = 4 datasets), a final sample of N = 461 participants (N = 116 males, N = 345 females) remained. The sample was derived from the Ulm Gene Brain Behavior Project (Ulm University, Ulm, Germany) and, therefore, partly overlaps with samples of other studies reporting data derived from this project. These other studies, however, do not overlap thematically with the present study. The mean age of the present German sample was M = 22.31 years (SD = 5.06 years) with a median of 21 years. The majority of the participants were university students (N = 419; 91%).

The initial Chinese dataset comprised N = 414 participants. One of the datasets of one participant who took part in the study twice (N = 1) was excluded. Therefore, the final sample consisted of N = 413 participants (N = 268 males, N = 145 females). Several participants of this sample (N = 284) were derived from the Chengdu Gene Brain Behavior Project (University of Electronic Science and Technology of China (UESTC), Chengdu, China) and, therefore, this sample partly overlaps with samples of other studies reporting data of this project. The remaining Chinese participants were recruited at Beijing University of Civil Engineering and Architecture, Bejing, China. The mean age of the participants of the present Chinese sample was M = 21.19 years (SD = 2.41 years) with a median of 21 years. The majority of the participants were university students (N = 369; 89%).

In order to investigate the English translation of the Attitude Towards Artificial Intelligence (ATAI) scale with regards to its psychometric properties, N = 84 participants (N = 19 males, N = 65 females, age: M = 25.21 years, SD = 7.71 years, median = 23 years), who were native English speakers, completed the English version of the ATAI scale (see section on Self-Report Measures). These participants were recruited in the UK at Goldsmiths, University of London, London, England. The majority of the participants were university students (N = 69; 82%).

The data is available from the authors upon reasonable request (as we did not specifically ask participants for their consent to publish anonymized data, we cannot make the data freely available).

2.2 Procedure, Ethics, and Consent

The studies were conducted online in Germany, China, and the UK via the SurveyCoder tool (https://ckannen.com/). The local ethics committees at Ulm University, Ulm, Germany and the UESTC, Chengdu, China approved the present studies. There was no separate proposal submitted to Goldsmiths, University of London, London, England. All participants gave informed electronic consent prior to participation.

2.3 Self-Report Measures

2.3.1 Item Generation

Shortly before this research was conducted, a media debate was occurring in Germany focussing on the question on whether or not the rising impact of AI in daily life would result in a loss of jobs and/or would have some form of detrimental effects on humankind. In this debate, it became obvious that there are groups of people who do not openly embrace these technologies, while others use services, such as Alexa and Siri, very comfortably and without concern. The argument that AI will be the cause of many job losses was mentioned frequently in the context of reasons to fear AI. On the contrary, the opinion that people can live and work more effectively by using AI products was discussed in the context of acceptance of AI (see also representative study in Germany by Marsden [20]). Moreover, several AI products already in use in everyday life were discussed (e.g. Siri and Alexa). In brief, the key points of argument of this debate were the basis for the construction of the proposed scale assessing the attitude towards AI (ATAI scale) and additional items measuring the willingness to use specific AI products.

The items of the ATAI scale and the items about specific AI products were developed in German language, translated into Chinese and English, and then back translated into German independently by two bilingual researchers (forward and backward translations). Following this, the German original and the back translations were carefully checked for compatibility and the translations were adjusted if necessary. Additionally, native speakers checked the translations for linguistic and grammatical correctness.

2.3.2 Attitude Towards Artificial Intelligence Scale

The ATAI scale consists of five items. The German, Chinese, and English versions of the questionnaire are presented in

Table 1 Items of the ATAI scale in German, Chinese, and English language

German version	
01.	Ich habe Angst vor künstlicher Intelligenz.
02.	Ich vertraue künstlicher Intelligenz.
03.	Künstliche Intelligenz wird die Menschheit zerstören.
04.	Künstliche Intelligenz wird eine Bereicherung für die Menschheit sein.
05.	Künstliche Intelligenz wird für viel Arbeitslosigkeit sorgen.
Chinese version	
01、	我害怕人工智能。
02、	我信任人工智能。
03、	人工智能将会摧毁人类。
04、	人工智能将会丰富人类。
05、	人工智能将会导致大量失业。
English version	
01.	I fear artificial intelligence.
02.	I trust artificial intelligence.
03.	Artificial intelligence will destroy humankind.
04.	Artificial intelligence will benefit humankind.
05.	Artificial intelligence will cause many job losses.

ATAI: Attitude Towards Artificial Intelligence

Table 1. An 11-point Likert scale ranging from 0 = "strongly disagree" to 10 = "strongly agree" was used as response scale. An 11-point Likert scale was used to get a fine-grained picture with respect to a person's attitude towards AI, in particular as a short measure was constructed, here. Explicitly, it is mentioned that future research endeavors should check if other forms of Likert scaling are more appropriate in the context of the present scale.

2.3.3 Trust in and Usage of Several Specific AI Products

Participants from Germany and China were additionally introduced to five AI products by means of a picture and accompanying descriptive sentences. These AI products were self-driving cars, Siri, Alexa, Pepper, and Erica. After the introduction to each product participants were asked to rate their trust in each product as well as their willingness to use/interact with the product on an 11-point Likert scale ranging from 0 = "strongly disagree" to 10 = "strongly agree". Lastly, participants answered with "yes"/"no" when questioned if they actually use/interact or have used / interacted with each of the specific AI products.

Please note that in the initial online survey (which is presented in the main manuscript) the items on AI products were presented before the ATAI scale. Also, a short introduction about AI in daily life was presented alongside these items. In order to exclude the possibility of the introduction influencing the results regarding the ATAI scale and its associations with the AI product items (e.g. the willingness to use them), we conducted a control survey with N = 82 participants from China. In the control survey, neither an introduction on AI, nor any information about the fact that the products were AI products was given. The results of the sample of the control survey are presented in the Supplementary Material. As the results are similar to the results presented in the main manuscript, we conclude that the introduction did not bias participants' response style.

2.4 Statistical Analyses

All analyses were implemented using the statistical software R version 3.5.2 [21], R-Studio version 1.1.463 [22], and several R-packages such as car [23], dplyr [24], effsize [25], gmodels [26], GPArotation [27], Hmisc [28], lavaan [29], ppcor [30], psych [31], and semTools [32].

First, the factorial structure of the ATAI scale was investigated by means of principal component analyses (PCAs) indicating a two-component structure in each of the three samples. The two components were rotated using the oblimin rotation to allow for correlations between the components. The two-factorial model based on the PCAs was tested by means of confirmatory factor analyses (CFAs), followed by testing internal consistencies (by means of Cronbach's α) of the two ATAI scales in each sample. Also, measurement invariance of the two-factorial model was tested across the three samples.

The two ATAI scales derived from the PCAs showed a skewness and kurtosis of less than ± 1 in nearly all (sub-) samples (split by country/country and gender) from Germany, China, and the UK. Only in the Chinese male subsample the kurtosis of the ATAI Acceptance scale was 1.31. Therefore, a normal distribution was assumed for the two scales [33] given the negligible deviation in the Chinese male sample, only.

Accordingly, correlations of the ATAI scales with age were calculated by means of Pearson correlations to check whether age should be treated as a control variable in further analyses. Differences between males and females, countries, and the gender by country interaction effect on the two ATAI scales were investigated using a multivariate multifactorial ANCOVA with age as control variable (see Sect. 3) and subsequent multifactorial ANCOVAs.

To validate the ATAI scale, correlations between the scores in the two ATAI scales and the items on the willingness to use specific AI products were calculated in the German and Chinese samples. As some of the items assessing the willingness to use specific AI products did show a marked deviation from the normal distribution in accordance with the criteria by Miles and Shevlin [33] in at least one of the (sub-)samples, we opted for partial Spearman correlations with age included as covariate (see Sect. 3). These correlations were also calculated separately for males and females in the German and Chinese samples.

Please note that there is an overlap in the wording between the second item of the ATAI scale ("I trust …") and the items on trust in the AI products. Therefore, we only report correlations between the ATAI scale and the items on the willingness to use the specific AI products. The simultaneous use of the word "trust" could potentially lead to higher correlations and, therefore, an overestimation of the underlying correlations.

Lastly, all analyses were also calculated based on a sample excluding all univariate outliers in the ATAI scales (N = 1 in the German sample, N = 11 in the Chinese sample, N = 0 in the sample from the UK), classified by the formula defined by Tukey [34]. The results did not differ meaningfully depending on whether outliers were in- or excluded. Therefore, we decided to present results including all participants, including those who were classified as univariate outliers.

3 Results

3.1 Principal Component Analyses of the ATAI Items

The PCAs revealed two eigenvalues greater than 1 in each sample (Germany: 2.26, 1.06; China: 2.38, 1.20; UK: 2.31, 1.11), allowing for the extraction of two components. The item loadings on the oblimin rotated components reflected the wording of the items. Specifically, items reflecting positive attitudes towards AI (items 02, 04) loaded positively on one component (more specifically, on the second component with smaller eigenvalues), while loading from weakly positively to negatively on the other component (more specifically, the first component with higher eigenvalues). Items that represent negative opinions towards AI (items 01, 03, 05) showed the opposite pattern.

3.2 Confirmatory Factor Analyses, Reliabilities, and Measurement Invariance of the ATAI Scale

The two components extracted in the PCAs were labelled Acceptance (items 02, 04) and Fear (items 01, 03, 05). CFAs revealed negative associations between the two factors and, for the most part, an acceptable model fit for the two-factorial structure in all three samples (Germany: CFI: 0.976, TLI: 0.940, RMSEA: 0.075, SRMR: 0.032; China: CFI: 0.870, TLI: 0.676, RMSEA: 0.202, SRMR: 0.079; UK: CFI: 0.933, TLI: 0.833, RMSEA: 0.127, SRMR: 0.059) [35]. The standardized loadings of the items on the two factors are presented in Table 2. However, several fit indices indicated a non-satisfactory model-fit for the Chinese sample. This was most likely due to the fifth item weakly loading (0.23) on the Fear factor in the Chinese sample. A decision was made to keep the item for further analyses given the acceptable model fit for the samples from Germany and the UK. This topic is discussed in more detail in the discussion section of the present work.

Table 2 Standardized loadings of the items of the ATAI scale on the two factors in the samples from Germany, China, and the UK according to the CFAs

	Germany (N = 461)		China (N = 413)		UK (N = 84)	
	Acceptance	Fear	Acceptance	Fear	Acceptance	Fear
ATAI 02	0.69		0.78		0.74	
ATAI 04	0.71		0.74		0.64	
ATAI 01		0.83		0.81		0.82
ATAI 03		0.64		0.69		0.70
ATAI 05		0.42		0.23		0.29

Table 3 Mean values and standard deviations (in parentheses) of the two ATAI scales in the samples from Germany, China, and the UK

	Germany			China			UK		
	Total (N = 461)	Males (N = 116)	Females (N = 345)	Total (N = 413)	Males (N = 268)	Females (N = 145)	Total (N = 84)	Males (N = 19)	Females (N = 65)
	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)
ATAI									
Acceptance	4.81 (1.90)	5.75 (1.96)	4.50 (1.78)	6.88 (2.03)	6.99 (2.00)	6.67 (2.06)	5.22 (1.73)	5.92 (2.05)	5.02 (1.59)
Fear	4.64 (1.94)	4.04 (1.97)	4.84 (1.89)	4.24 (1.95)	4.20 (1.96)	4.31 (1.96)	5.15 (1.87)	4.93 (2.03)	5.22 (1.83)

Range of response scale: 0–10. The observed range of the ATAI Acceptance scale was 0–10 in the total German sample, 0–10 in the total Chinese sample, and 0.50–8.50 in the total sample from the UK. The observed range of the ATAI Fear scale was 0–10 in the total German sample, 0–10 in the total Chinese sample, and 1.67–9.33 in the total sample from the UK

The internal consistencies of the Acceptance and Fear scales were $\alpha = 0.65$ and $\alpha = 0.66$ in the German sample, $\alpha = 0.73$ and $\alpha = 0.61$ in the Chinese sample, and $\alpha = 0.64$ and $\alpha = 0.65$ in the sample from the UK. We deemed these values as acceptable given the low number of items per scale.

Tests on measurement invariance revealed that configural invariance (see model fit) and equal loadings can be assumed across the three samples (delta $X^2 = 7.77$, $p = 0.255$).

3.3 Descriptive Statistics, Correlations with Age, and Country and Gender Differences

Descriptive statistics of the ATAI Acceptance and Fear scales derived from the PCAs are presented in Table 3 for each sample separately. Descriptive statistics of the items on the willingness to use the specific AI products are presented in the Supplementary Material alongside descriptive statistics on the items on whether participants actually use(d)/interact(ed) with specific AI products.

Age did not correlate significantly with any of the two ATAI scales in the German sample, but with the Acceptance scale in the Chinese sample ($r = 0.12$, $p = 0.019$), and with the Fear scale in the sample from the UK ($r = -0.31$, $p = 0.005$). When using Spearman correlations (age was not normally distributed in all samples), some more correlations turned out to be significant.

A multivariate multifactorial ANCOVA on differences in the two ATAI scales revealed significant effects of gender ($F(2,950) = 9.22$, $p < 0.001$, $\eta_p^2 = 0.019$), country ($F(4,1902) = 37.80$, $p < 0.001$, $\eta_p^2 = 0.074$), and the gender by country interaction ($F(4,1902) = 3.26$, $p = 0.011$, $\eta_p^2 = 0.007$), but not of age ($F(2,950) = 1.63$, $p = 0.073$, $\eta_p^2 = 0.006$). Further multifactorial ANCOVAs revealed that males scored higher than females in the ATAI Acceptance scale ($F(1,951) = 18.33$, $p < 0.001$, $\eta_p^2 = 0.019$). No significant gender effect was observed on the ATAI Fear scale ($F(1,951) = 3.36$, $p = 0.067$, $\eta_p^2 = 0.004$). Moreover, the samples from the three countries differed significantly in both ATAI scales (Acceptance: $F(2,951) = 72.82$, $p < 0.001$, $\eta_p^2 = 0.133$; Fear: $F(2,951) = 6.27$, $p = 0.002$, $\eta_p^2 = 0.013$) with the Chinese sample showing highest scores in the Acceptance scale and lowest scores in the Fear scale compared to the samples from Germany and the UK. It should be noted, though, that no scalar measurement invariance was found across the samples from the different countries. Therefore, an elaborate discussion on the interpretation of the differences between countries can be found in the discussion section. The gender by country interaction was significant on both scales (Acceptance: $F(2,951) = 5.46$, $p = 0.004$, $\eta_p^2 = 0.011$; Fear: $F(2,951) = 3.10$, $p = 0.046$, $\eta_p^2 = 0.006$). In the samples from Germany and the UK, males scored markedly higher on the Acceptance and lower on the Fear scale compared to females. In the Chinese sample, a trend in the same direction was visible, but to a smaller extent. Please note that the explanations on the effects of country and the gender by country interaction term rely on the descriptive statistics presented in Table 3.

3.4 Correlations Between the two ATAI Scales and the Items on the Willingness to Use Specific AI Products

Partial Spearman correlations (controlled for age) between the ATAI Acceptance and Fear scales and the items on the willingness to use specific AI products for the German and Chinese samples are presented in Table 4.

As can be seen in Table 4, the ATAI Acceptance scale correlated substantially with all items on the willingness to

Table 4 Partial Spearman correlations between the two ATAI scales and the items on the willingness to use specific AI products in the samples from Germany and China

	Germany (N = 461)		China (N = 413)	
	Acceptance	Fear	Acceptance	Fear
Self-driving cars	$r_s = 0.47$, $p < 0.001$	$r_s = -0.25$, $p < 0.001$	$r_s = 0.46$, $p < 0.001$	$r_s = -0.19$, $p < 0.001$
Siri	$r_s = 0.31$, $p < 0.001$	$r_s = -0.12$, $p = 0.009$	$r_s = 0.35$, $p < 0.001$	$r_s = -0.10$, $p = 0.046$
Alexa	$r_s = 0.36$, $p < 0.001$	$r_s = -0.12$, $p = 0.012$	$r_s = 0.45$, $p < 0.001$	$r_s = -0.14$, $p = 0.005$
Pepper	$r_s = 0.39$, $p < 0.001$	$r_s = -0.13$, $p = 0.007$	$r_s = 0.39$, $p < 0.001$	$r_s = -0.23$, $p < 0.001$
Erica	$r_s = 0.34$, $p < 0.001$	$r_s = -0.18$, $p < 0.001$	$r_s = 0.34$, $p < 0.001$	$r_s = -0.15$, $p = 0.003$

All correlations are controlled for age. When manually applying a Bonferroni correction for multiple testing ($\alpha = 0.05/(2 \times 5) = 0.0050$; as two ATAI scales were correlated with items on the willingness to use five specific AI products) not all correlations remain significant. As such, the associations between the ATAI Fear scale and the items on the willingness to use (1) Siri, (2) Alexa, and (3) Pepper in the German sample, and the correlations between the ATAI Fear scale and the items on the willingness to use (1) Siri and (2) Alexa (more exact p-value: 0.00525) in the Chinese sample would not remain significant. Such a Bonferroni correction can be deemed as too strict, though. Firstly, we hypothesized a positive correlation between the attitude towards AI and the willingness to use AI products a-priori (hence, also negative correlations between the ATAI Fear scale and willingness to use specific AI products); secondly, all products tested belong to the area of AI products

Table 5 Partial Spearman correlations between the two ATAI scales and the items on the willingness to use specific AI products in the samples from Germany and China, split by gender

	Germany				China			
	Acceptance		Fear		Acceptance		Fear	
	Males (N = 116)	Females (N = 345)	Males (N = 116)	Females (N = 345)	Males (N = 268)	Females (N = 145)	Males (N = 268)	Females (N = 145)
Self-driving cars	$r_s = 0.27$, $p = 0.004$	$r_s = 0.47$, $p < 0.001$	$r_s = -0.13$, $p = 0.154$	$r_s = -0.24$, $p < 0.001$	$r_s = 0.45$, $p < 0.001$	$r_s = 0.47$, $p < 0.001$	$r_s = -0.17$, $p = 0.005$	$r_s = -0.23$, $p = 0.005$
Siri	$r_s = 0.26$, $p = 0.004$	$r_s = 0.35$, $p < 0.001$	$r_s = -0.10$, $p = 0.307$	$r_s = -0.14$, $p = 0.009$	$r_s = 0.37$, $p < 0.001$	$r_s = 0.31$, $p < 0.001$	$r_s = -0.10$, $p = 0.090$	$r_s = -0.07$, $p = 0.389$
Alexa	$r_s = 0.38$, $p < 0.001$	$r_s = 0.36$, $p < 0.001$	$r_s = -0.13$, $p = 0.181$	$r_s = -0.11$, $p = 0.050$	$r_s = 0.42$, $p < 0.001$	$r_s = 0.47$, $p < 0.001$	$r_s = -0.14$, $p = 0.023$	$r_s = -0.12$, $p = 0.151$
Pepper	$r_s = 0.29$, $p = 0.001$	$r_s = 0.39$, $p < 0.001$	$r_s = 0.06$, $p = 0.528$	$r_s = -0.16$, $p = 0.002$	$r_s = 0.40$, $p < 0.001$	$r_s = 0.37$, $p < 0.001$	$r_s = -0.18$, $p = 0.004$	$r_s = -0.31$, $p < 0.001$
Erica	$r_s = 0.22$, $p = 0.019$	$r_s = 0.31$, $p < 0.001$	$r_s = -0.10$, $p = 0.276$	$r_s = -0.15$, $p = 0.007$	$r_s = 0.34$, $p < 0.001$	$r_s = 0.35$, $p < 0.001$	$r_s = -0.11$, $p = 0.069$	$r_s = -0.21$, $p = 0.010$

All correlations are controlled for age. When manually applying a Bonferroni correction for multiple testing ($\alpha = 0.05/(2 \times 5 \times 2) = 0.0025$; as two ATAI scales were correlated with items on the willingness to use five specific AI products in both males and females) not all of the significant correlations listed in Table 5 remain significant. As such, the correlations between the ATAI Acceptance scale and the items on the willingness to use (1) self-driving cars, (2) Siri, and (3) Erica in German males would not remain significant. In German females, the correlations between the ATAI Fear scale and the items on the willingness to use (1) Siri, (2) Alexa, and (3) Erica would not remain significant. Also, the correlations between the ATAI Fear scale and the items on the willingness to use (1) self-driving cars (in Chinese males as well as females), (2) Alexa (in Chinese males), (3) Pepper (in Chinese males), and (4) Erica (in Chinese females) would not remain significant. Such a Bonferroni correction can be deemed as too strict, though. Firstly, we hypothesized a positive correlation between the attitude towards AI and the willingness to use AI products a-priori (hence, also negative correlations between the ATAI Fear scale and willingness to use specific AI products); secondly, all products tested belong to the area of AI products

use specific AI products in both samples from Germany and China. These correlations were all positive. In contrast, the ATAI Fear scale correlated negatively with these items in both samples from Germany and China. The observed associations were weaker compared to the correlations between the ATAI Acceptance scale and the items on the willingness to use the specific AI products.

It is important to note that none of the correlations differed significantly between the German and Chinese (total) samples (all p-values of Fisher's z-tests > 0.107).

As seen in Table 5, also in the male and female German and Chinese samples, there were moderate to strong positive correlations of the ATAI Acceptance scale with the items on the willingness to use specific AI products. On the other hand, there were weak to moderate negative correlations of the ATAI Fear scale with these items (several of the correlations were not significant). There was only one exception: The correlation between the ATAI Fear scale and the item on the willingness to use Pepper in the German male sample was just above zero.

There were significant differences between German males and females in the correlations between the ATAI Acceptance scale and the item on the willingness to use self-driving cars ($z = 2.22$, $p = 0.026$) and the correlations between the ATAI Fear scale and the item on the willingness to use Pepper ($z = 2.08$, $p = 0.037$). No significant differences in any of the correlations were found between Chinese males and females (all p-values of Fisher's z-tests > 0.176).

There was a significant difference between German and Chinese males in the correlations between the ATAI Fear scale and the item on the willingness to use Pepper ($z = 2.11$, $p = 0.035$). No significant differences in any of the correlations were found between German and Chinese females (all p-values of Fisher's z-tests > 0.128).

4 Discussion

The present study aimed to develop and introduce a short, valid, and reliable measure to assess the Attitude Towards Artificial Intelligence (ATAI scale) in the different languages of German, Chinese, and English.

PCAs in each sample from Germany, China, and the UK consistently demonstrated that the ATAI scale consists of two negatively related scales describing Acceptance and Fear of AI. CFAs revealed mostly acceptable model fits in the three different samples. However, unexpectedly, the fifth item ("Artificial intelligence will cause many job losses.") did not load strongly on the ATAI Fear factor, especially in the Chinese sample (standardized loading: 0.23). A similar pattern was found in the German and UK samples as well, where the loading of the same fifth item was not particularly high: Germany: 0.42, UK: 0.29. Excluding the fifth item would lead to a higher model fit, especially in the Chinese sample. Nevertheless, invariance analyses would still confirm "only" equal loadings. Overall, these findings indicate that job loss due to AI might not be a reason to have a negative attitude or even fear AI, especially in the present Chinese sample. This might be explained by the fact that part of the data (N = 284) was collected at a technology-oriented university (UESTC, Chengdu, China). Hence, the students here are most likely taught to create and work alongside AI. Their employment after university will potentially include working with AI products. Additionally, with an unemployment rate of around 4% [36], unemployment may not be considered a serious problem by Chinese students at all. However, according to the present results, students in Western countries also do not seem to see job loss as a serious reason to fear AI. In other samples that include more employed people being at a risk of losing their jobs due to AI progress, the fifth item might load more strongly on the ATAI Fear factor. Therefore, future researchers need to decide on the inclusion or exclusion of the fifth item by taking into account specific sample characteristics.

Of major interest to the discussion on fear of AI and its association with job loss is a recent work by Granulo, Fuchs, and Puntoni [37]. In a series of studies, the researchers found that people prefer replacement of other human employees by other humans as opposed to by machines/robots/new technologies. But when it comes to their own current job and its potential loss, people prefer being replaced by machines/robots/new technologies rather than being replaced by other humans. The latter result was explained by higher self-threat when the own job is at risk to be carried out by another human as opposed to by a machine/robot/new technology [37]. These findings indicate that the perspective, whether one's own or another one's job is at risk for being replaced by AI, might also influence the attitude towards AI.

The Chinese sample showed highest scores on the ATAI Acceptance scale and lowest scores on the ATAI Fear scale (exception: Chinese males showed descriptively higher scores in the Fear scale than German males). This is in accordance with the enormous amount of human resources, time, and money invested into AI in China [38, 39]. It is also in line with the rising impact of Chinese research in the field of AI [40]. However, it might also be partly explained by recruitment of some participants at a technologically oriented university (UESTC, Chengdu, China), as previously mentioned. In line with previous literature on technology acceptance [18, 19], males demonstrated higher scores in the ATAI Acceptance scale than females, who in turn showed higher scores in the ATAI Fear scale. This gender difference was, however, substantially smaller in the Chinese sample. Perhaps, gender differences in technological research questions are generally smaller in China, though this implication requires further exploration. Also, the fact that we collected part of the data from China at a more technologically oriented university (UESTC, Chengdu, China) might explain the lack of significant gender differences in the Chinese sample. Overall, the findings from Germany, the UK, and the trend in China are in line with earlier research demonstrating that males are more interested in, and have a more positive attitude towards technologies [18, 19]. However, here it is worth mentioning that there is conflicting evidence [41]. These contradicting findings might be explained by the fact that gender differences in attitudes towards technology and technology acceptance vary depending on the domain of the technology [42]. For example, the notion that males generally hold more favourable attitudes towards technology has been challenged in recent years by females using specific digital platforms, such as online social networks, more than males do [43]. These findings point toward investigating different fields of AI and its products in future studies when investigating gender effects.

Moreover, in the present study the validity of the ATAI scale was tested by relating it to the items on the willingness to use specific AI products. Here, there are sound implications for the proposed measure, in that the ATAI Acceptance scale was positively associated with these items, whereas the ATAI Fear scale was inversely correlated with these items in both the German and Chinese samples.

Nevertheless, some limitations of the study need to be discussed. First of all, the samples are skewed with respect to the gender distribution. Specifically, there was a higher number of females in the German sample and the sample from the UK, and a higher number of males in the Chinese sample. However, this problem was counteracted by presenting descriptive statistics and correlations with the items on the willingness to use specific AI products separately for males and females of each sample (of note, correlations with the willingness to use specific products were not calculated in the sample from the UK). These correlations were, with single exceptions, equally pronounced across males and females. Moreover, the present samples mostly comprised rather young adults. Therefore, the generalizability of the results and applicability of the scale in older (or even younger) samples need to be investigated in future research. Additionally, the items were constructed based on rational choices and content of recent media debates. However, the items were not extracted out of a bigger item pool based on an exploratory factorial analysis/PCA. This might be seen as a shortcoming of the questionnaire. Nevertheless, the present scale clearly provides high face validity. As can be seen from the results, it seems to validly assess one's attitude towards AI; but associations with other relevant constructs such as the Technology Acceptance Model (see below) need to be tested in the future. Moreover, we mention that we aimed to develop a brief scale to assess an individual's attitude towards AI in different languages (here English, Chinese, and German) and this limited us in generating a large item pool immediately being available in the aforementioned languages. Such a large item pool brings advantages in terms of choosing the best possible items to assess latent constructs such as assessed with the ATAI scale but this was not possible against the background of lacking economic resources. Therefore, we name this explicitly as a limitation, in particular when future researchers aim to design scales giving insights into facets of such an attitude. This said, we believe our measure gives highly needed insights into general, broad attitudes towards AI, but without giving insights into such facets. Lastly, equal loadings could be assumed across all samples. However, scalar measurement invariance (equal intercepts; the next step after equal loadings) was not found. Therefore, the results regarding the mean value comparison of the two ATAI scales between the samples from different countries need to be interpreted with caution. Yet, we are of the opinion that reporting these results is important for understanding the data and for completeness of the reported results. Additionally, the results in all samples, especially the correlations between the ATAI scales and the items on the willingness to use specific AI products, were similar, underlining the cross-cultural applicability of our measure (see also a recent comment by Montag [44] pointing out that cross-cultural research might be an effective solution for the replication crisis).

Importantly, the present ATAI scale measures the overall attitude towards AI. It might also be interesting to use this scale to address the attitude towards AI in specific contexts, such as traffic, medicine, etc. Moreover, we would like to acknowledge that AI has an emerging impact on daily life beyond the current examples of AI products. It was intentional to focus on products, which are either already in use in everyday life or can be explained to and understood by laypersons not working in the field of AI. Therefore, the present study represents a mere starting point to develop broader measures to assess one's attitude towards AI. This could be the inclusion of facets such as the preference for interactions with AI products instead of interactions with real humans, or scales based on the Negative Attitude towards Robots Scale [45]. Additionally, future studies should investigate the reasons why people tend to accept or fear AI. For example, it could be due to the (or lack of) experience with AI products, societal norms, or subjective attitudes. Besides that, based on the Technology Acceptance Model, one could further investigate the impact of perceived ease of usage and perceived usefulness of AI products on the attitude towards distinct AI products [46, 47].

In conclusion, the present study contributes to the field of AI research by providing a short, reliable, and valid measure of the attitude towards AI as a starting point for further investigations of AI in the future.

Author Contributions CM designed the present study including the questionnaire to assess the Attitude Towards Artificial Intelligence (ATAI scale). CS and CM drafted the present manuscript. CS conducted the statistical analyses. MZ and PS have been responsible for the Chinese translation process of the questionnaires. CS, JW, ML, and BB conducted the data collection in China, whereas CS and RS collected the German data. MS, CM, and CS were responsible for the translation process in English language. Moreover, MS conducted the data collection in the UK. CS, HS, and BB conducted data collection for the control survey. All statistical analyses were independently checked by HS. All authors read, revised and approved the final version of the manuscript.

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Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest statement.

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