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# What factors predict the type of person who is willing to fly in an autonomous commercial airplane?

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ABSTRACT

There has been much discussion and research lately highlighting autonomous commercial flight, with most of the focus on engineering design and legal issues. Some prior research has shown that many people are generally not willing to fly in fully autonomous aircraft; however, there is a significant proportion of society that is willing to use these types of airplanes. It is critical for the aviation industry to be able to identify these individuals as they will likely be the early adopters. The current study was designed with the purpose of determining what factors predict the type of person who would be willing to fly in fully autonomous commercial airplanes. We provided a hypothetical scenario to 1042 potential passengers from the United States and asked them to rate their willingness to fly in that situation. We also collected demographic data, along with ratings of various scales to determine what predictors were significant in a regression model. In Stage 1, we built the model from a dataset of 522 participants and determined that the significant factors were familiarity with autonomous flight, fun factor, general wariness of new technology, happiness, fear, age, and educational level. This model accounted for 85.9% of the variance in the data. In Stage 2, we tested the model with 520 participants and found excellent model fit. We discuss the practical and theoretical implications of these findings.

## 1. Introduction

Consumer perceptions and attitudes can strongly influence the success and failure of new technologies. There have been several studies that have examined the relationship between multiple variables (e.g., gender, nationality, flight distance, weather, number of pilots) and their influence on individuals' willingness to fly (WTF) on a fully autonomous flight (Mehta et al., 2017; Ragbir et al. 2018; Rice et al., 2014; Rice and Winter 2015; Winter et al., 2015). Vance and Malik (2015) investigated factors of willingness to fly, but primarily from the perspective of aviation and technology professionals. Their study found the integrity characteristics of the airline has the most positive influence on willingness to fly while concerns for life insurance liability had the most negative influence. MacSween-George (2003) provided descriptive data on autonomous aircraft for cargo and passenger operations. Participants were most favorable toward cargo operations, which aligns with later research on that topic (Winter et al., 2015). When provided with information on autonomous aircraft operations, MacSween-George (2003) found that participants could be persuaded in favor of autonomous aircraft operations. However, to date, there is no literature that provides a *predictive model* of an individual passenger's WTF in an autonomous aircraft. With the aviation industry's increased use of automation, it is vital to understand passengers' views and WTF on an autonomous flight. Many factors can influence an individual's WTF; thus, the purpose of this study was twofold: (1) determine which factors influenced passengers' WTF to fly in an autonomous commercial airliner and (2) validate a predictive model of WTF in an autonomous aircraft for future use.

### *1.1. A brief background of automated technologies and human interaction*

The development of automated technologies has reduced human error and assisted in complex repetitive tasks (Hoff and Bashir, 2015). The use of automation can be evaluated through many innovative industries such as the medical profession and aviation. Although the benefits of automation in aviation are well-established, limited research has explored the perceptions and attitudes of the individuals who will be utilizing these technologies. Certainly, the demand for air travel has increased throughout the years and continues to increase today. According to the Federal Aviation Administration (2018), the United States (U.S.) had around 827,000 pilots in 1987. Since then, the number of pilots has decreased by 30% (s). Many aviation companies have

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warned of the imminent pilot shortage with projections estimating that airlines worldwide will need 635,000 new pilots within the next 20 years (Hemmerdinger, 2018). It is possible that increased automation or fully autonomous aerial vehicles may be able to fill or supplement that shortage. However, a current unknown is who would be the types of individuals and what factors would predict their willingness to fly in this type of a scenario.

Considering the levels of automation available commonly today and given the capabilities of current technology, humans have been able to accomplish tasks more safely and effectively than without the use of automation. These advances in technology have guided automation to be used as an information processing resource, especially in aviation, however, automation adaptation follows various levels or a spectrum. Sheridan and Verplank (1978) described automation as a scale that comprises levels, and the levels of information automation is able to provide to the human. An extension of these levels was later proposed suggesting a concept of four information-processing stages: (a) information acquisition, (b) information analysis, (c) decision making, and (d) action (Parasuraman and Wickens, 2008). There is a noticeable similitude to the human information processing system within these stages, and therefore, can impact an individual's trust of an automated system. It is possible that this trust could have an impact on a person's willingness to fly about an autonomous aircraft.

Many prior studies have investigated trust and automation (e.g., Hoff and Bashir, 2015; Lee and See, 2004), and the research suggests that trust plays a critical role in human-technology interactions. Many factors can influence an individual's trust in automation, including age, culture, and social behaviors (Parasuraman and Wickens, 2008). The increased use of sophisticated technologies, especially the complexity and uncertainty that derives with automation, may discourage people from utilizing these resources (Lee and See, 2004). Karvonen (2001) examined consumer trust in business and marketing services. The results suggested that the majority of individuals trusted a simplistic design and displayed uncertainty towards the complex design. Trust has emerged as an essential element that may support the implementation and utilization of advanced technologies. Perhaps, with continued exposure to these new technologies, individuals may find the systems used less complex and allow for the progression of these technologies in various domains. These factors may also influence the willingness to fly ratings of participants.

### 1.2. Justification of possible predictors

It is possible that certain predictors can help identify the type of individuals who would be WTF on a fully autonomous flight. Understanding consumers' perceptions and attitudes towards automation is imperative as they provide the foundation for the development of technology's future use. Various factors can influence an individual's WTF such as gender, ethnicity, emotions, and even price.

Prior research suggests that decision-making and risky behavior may vary based on systematic differences between males and females (Byrnes et al., 1999; Eckel and Grossman, 2008; Heidl et al., 2010). Eckel and Grossman (2008) examined the experimental results of risk aversion between genders and found that in general, males were more likely to participate in risky behavior than females. Also, there have been numerous studies that support the impression that men and women perceive and view risk in different ways. For example, investigations into gender differences of drug use suggest that males are more likely to engage in the use of drugs (e.g., alcohol, psychedelics, heroin) and perceived the idea as less risky than females (Spigner et al., 1993). Furthermore, studies that have explored reactions to catastrophes of nuclear war, nuclear facilities, and environmental degradation indicated that women felt negatively towards these devastations (Eckel and Grossman, 2008; Flynn et al., 1994; Freudenburg and Davidson, 2007). New technology can be perceived as risky due to the uncertainty of the new product. Therefore, it is imperative to acknowledge that there are systematic differences between gender when it comes to decision-making and risky behaviors.

Another predictor that can influence an individual's WTF is ethnicity. The United States is a diverse and multiethnic country. Ethnicity is a term used to describe populations that have similar ancestries or common cultural heritage (Kenny and Briner, 2007). Although nations such as Asia and Africa acknowledge hundreds of ethnic groups, America categorizes its population into six groups: Hispanic, non-Hispanic white, American Indian/Alaska Native, black, and Asian/Pacific Islander (Sawe, 2016; United States Census Bureau, 2017). According to the U.S. Census Bureau (2017), approximately 77% of the people in America are white, about 18% are Hispanic or Latino, around 13.5% are black, 9% are Asian/Pacific Islander, and roughly 1.3% are American Indian/Alaska Native. Due to the strong presence of the Hispanic/Latino population in the U.S., the Census considers the ethnicity to be classified separately (United States Census Bureau, 2017).

There have been many studies have investigated how ethnicity influences social behavior, decision-making, and consumer habits (Dimofte et al., 2010; Kim and Kang, 2001; Trinh et al., 2018). Dimofte et al. (2010) examined consumer perceptions, attitudes, and purchase intentions on brand globality from three ethnic segments (Caucasians, African- American, and Hispanic) of U.S. consumers. Global brands can be described as well-known brands that are widely used within international markets (Dimofte et al., 2010). The results indicated that Caucasians viewed global brands less positively than African-American and Hispanic participants. This illustrates that consumers who are more optimistic towards global brands also have higher positive attitudes and are more likely to purchase (Dimofte et al., 2010). One reason for this outcome could be that the Caucasian population in America is viewed as relatively different than other ethnic groups. In that, Caucasians follow more of an individualistic view of self and embrace social independence while Asian, Hispanic, and African-American groups tend to favor groups and conformity (Pollitt, 1994).

Although there are noticeable differences between the majority and minority groups in America, there are also differences within the minority groups as well. Phinney (1996) explored global descriptions for ethnic groups in America citing many empirical articles validating these ethnic differences. African- American display characteristics of collective survival and interdependence (Phinney, 1996). Hispanics are said to be characterized as loyal with high levels of sacrifice for in-group members (Marín & Marín, 1991). While Asians, according to Abe-Kim (1995), focus on fulfilling obligations to themselves and their family. The general agreement within the literature is that ethnicity influences consumer behavior (Akir and Othman, 2010; Trinh et al., 2018). Consumer behaviors are likely governed by social norms that can potentially affect attitudes and behavior. Therefore, understanding the role ethnicity plays in individuals decision-making and willingness can help researchers improve strategies when introducing new technologies to different populations.

Emotions can also influence an individual's decision-making and WTF on an autonomous aircraft. There has been substantial research that has examined the relationship between emotion and its influence on decision-making (Forgas, 1995; George, 1991; Kahneman et al., 1982; Wright and Bower, 1992) stemming from behavioral decision theory. Behavioral decision theory suggests that doubtful decisions stem from cognitive processes in which an individual makes a logical inference among various options and chooses the option with higher positive results (Loewenstein and Lerner, 2003; Quartz, 2009). However, in recent years, researchers have recognized that humans are not always rational and will make decisions based on emotions, especially in the absence of necessary information (Loewenstein and Lerner, 2003). Mittal and Ross (1998) examined how positive and negative affect may influence strategic decision-making. The results indicated that participants who were in a positive mood viewed abstruse issues as an opportunity and were less likely to take risks as opposed to participants in a negative mood. Similarly, past research illustrates that

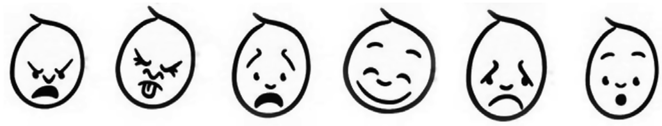

**Fig. 1.** Ekman and Friesen's (1971) six universal facial expressions. The images represented in order are: anger, disgust, fear, happiness, sadness, and surprise.

participants who are happy felt optimistic about future events and believed more positive events would ensue than sad participants (Wright and Bower, 1992).

Although, it is difficult for researchers to understand every single emotion humans experience, there are previous studies have examined universal emotions that most people (regardless of age, nationality, gender, etc.) can identify (Ekman and Friesen, 1971). There are six universal emotions people can recognize and identify: anger, disgust, fear, happiness, sadness, and surprise (Ekman and Friesen, 1971). Generally, researchers use basic photographs of facial behavior for each of the six emotions (See Fig. 1) to examine participant's representation of the emotion (Ekman and Friesen, 1971; Porter and Brinke, 2008).

Considering the influence of affect, consumer psychology research has shown that when people are in a good mood, they evaluate products more positively than people who are in a bad mood (Schwarz, 2002). Over the past two decades, evidence has shown that implicit and automatic processes govern social behavior (e.g., spontaneous inferences) (Uleman et al., 2008). Individuals routinely rely on spontaneous inferences and implicit theories when judging a new object or product (Kardes et al., 2004). Spontaneous inferences are based on affective reactions that surface unintentionally while implicit theories are individual's beliefs about the relationship between people and objects (Kardes et al., 2004; Uleman et al., 2008).

Hughes et al. (2009) examined the role of affect and ticket prices' influence on consumers WTF on an autonomous flight. The data suggested that there is a resemblance between the processes used to make judgments about products and the processes used to judge automation. Furthermore, the study also indicated that there was a correlation between price and quality. Participants were more positive of the automated aircraft when the ticket price was $1000 compared to $500 dollars. Notably, the high-priced ticket also increased participant ratings of feelings, trust, and confidence in the automated system (Hughes et al., 2009). The evidence that price is used as an indicator of quality is well-established. Scitovszky (1944) evaluated the problems associated with judging the quality of a product by price and proposed that "the habit of judging quality by price is not irrational but represents a belief that price is determined by competitive interplay of supply and demand" (p.100). In other words, quality and price are positively related with the perception that higher prices lead to greater quality and an increased willingness to purchase (Dodds et al., 1991). Since there are a variety of predictors that can influence WTF and decision-making, it is vital to recognize what factors negatively impact decisions to try new technology.

### *1.3. The rationale for scales used in this study*

To predict consumer's WTF on an autonomous aircraft five scales (see Appendix 4) were created that measured: complexity, familiarity, value, fun factor, and wariness of new technology. The rationale for using these five predictors derived from the technology acceptance model (TAM) (Davis, 1989). Over the past decades, TAM has been tested by several researchers for validation (Davis et al., 1989; Mathieson, 1991; Oh and Yoon, 2014). Davis et al. (1989) examined the ability to predict people's acceptance of computer technology. The results suggested that perceived usefulness and perceived ease of use strongly influenced acceptance. Later studies of TAM comprised these two components with additional factors to test an extension of TAM. Venkatesh and Davis (2000) embraced the TAM factors and created TAM 2 which integrated various exogenous variables (e.g., cognitive instrumental processes) which helped to further explicate the factors that strongly influenced accptance. Current models such as Unified Theory of Acceptance and Use of Technology (UTAUT) was formulated using eight information acceptance (Venkatesh et al., 2003). UTAUT was empirically tested and identified three direct determinants of intention to use: performance expectancy, effort expectancy, and social influence (Venkatesh et al., 2003).

Following a comprehensive search of scales, researchers concluded that discrepancies were present, including the length of published scales being too long for participants to sit through. This may discourage individuals from participating in or completing the entire survey. Thus, five scales were created and validated for the use of this study. There are five statements with Likert scale responses from strongly disagree to strongly agree. The full reporting of validation measures can be found in Appendix B.

### *1.4. Current study*

Some prior research has examined the relationship between various variables (e.g., gender, nationality, length of flight, weather, number of pilots, etc.) and their effect on consumer WTF in autonomous commercial airplanes; however, to date we have not seen any study that provides a predictive model of WTF based on a thorough list of demographics, emotions, and attitudes. The current study seeks to fill this gap in a two-stage process. First, we collected data across 20 potential predictors and created a descriptive model using backwards stepwise regression. Second, we collected another dataset to test this descriptive model for fit, with the goal of producing a predictive model that would help future researchers and airlines to understand what type of person is likely to be willing to fly on autonomous aircraft.

## 2. Methods

### *2.1. Participants*

A total of 1042 (502 females) adults participated for compensation. The age range was from 18 to 77 years old, and the mean age was 37.64 ($SD$ = 11.25) years. All participants were recruited from Amazon's ® Mechanical Turk ® (MTurk), which is an online portal where participants receive compensation for their participation in surveys (Buhrmester et al., 2011; Germine et al., 2012; Rice et al., 2017). To ensure high-quality data, participants needed to have completed more than 100 prior tasks and have approval ratings of 98% or higher.

### *2.2. Materials, stimuli, and procedure*

Participants were first provided with an electronic consent form and they were presented with instructions. Following this, they were asked to fill out a series of scales described in the Introduction, which measured their responses to: (a) complexity of aircraft automation, (b) familiarity with aircraft automation, (c) value of aircraft automation, (d) fun factor of using autonomous aircraft, and (e) their general wariness of new technology. A description of these scales is provided in detail in Appendix B.

Subsequently, participants were given the following hypothetical scenario: *Imagine a situation where you have no other option of getting from one city to another except to ride in an autopiloted (fully autonomous) commercial airplane. This airplane has no human pilot and is fully automated. There is no yoke or pedals, and no way for anyone to manually take over the flying duties. There is a human pilot located at a ground station who can take over the flight via remote control in case of an emergency. The flight is a domestic flight of about 3 h long.* Next, they were presented with six faces that represented the six universal emotions described by Ekman and Friesen (1971). These can be found in Fig. 1. After being presented with each face in random order, participants were asked to rate how strongly they felt like each of the faces on a scale of 0–10, with 1 being “I do not feel this way at all” and 10 being “extremely feel this way.”

Next, participants were asked to respond to a Willingness to Fly scale (see Appendix A) that was developed and validated by Rice et al. (2015) using a five-point scale from strongly disagree to strongly agree. Following this, participants provided demographic information, including their gender, age, ethnicity, nationality, number of times per year they fly, how many family members they usually fly with, income, whether they usually fly for business or pleasure, what class of ticket they usually purchase, and their highest education level. Age, nationality, number of times per year flown, how many family members they usually fly with, and income were open-ended responses. The other variables were selected by multiple choice options. Lastly, participants were debriefed and compensated.

## 3. Results

The purpose of this study was to determine which factors influenced passengers’ WTF onboard an autonomous (fully automated with no human pilot) commercial airliner. Through this study, a prediction model of WTF in autonomous aircraft was also validated for future use. Twenty factors were tested for their predictive ability on passenger willingness. The items were perception of complexity of aircraft automation, familiarity with aircraft automation, value of aircraft automation, fun factor of using autonomous aircraft, and their general wariness of new technology, the emotions of anger, disgust, fear, happy, sad, and surprise, gender of the participant, age of the participant, ethnicity of the participant, frequency of travel in a year, number of family members typically travelling with the participant, seat type, yearly income of the participant, purpose of travel, and education level of the participant. For the design of this study, these items were treated as the independent variables.

The study utilized a correlational design and was broken down into two stages. A regression analysis performed in the first stage identified the factors that were significant predictors of WTF. The regression equation created in stage one was tested in stage two for its model fit capabilities with an independent second sample of data. The model fit analyses were conducted for validation of the model. G*Power was used to determine the minimum sample sizes for each stage. The parameters used were: 20 predictors, small estimated effect size of 0.15, power (beta) of 0.90, and alpha level of significance 0.05. The results showed a minimum sample size needed of 191 participants in each stage. Initial data analysis resulted in participants being removed due to incomplete responses yielding 1042 total usable participants with 522 and 520 participants for stage 1 and 2, respectively.

### 3.1. Stage 1

An initial data analysis was completed to verify the use of the data for statistical regression. A Durban-Watson value of 1.977 was calculated. With this value being close to 2, it can be assumed that the data meet the assumption of independence of residuals. Leverage values were all determined to be less than 0.2, thus indicating that no case had excessive leverage in the model. Additionally, all Cook's distances were below a value of 1, indicating that there were no influential points. Mahalanobis' distances were all below the critical value of 31.41 (highest observed 24.76), which indicates no outliers in the data. Multicollinearity was checked by all tolerance values being above 0.1. Lastly, the assumptions of homoscedasticity and normality were met through visual inspection of a residual histogram plot, P—P plots, and standardized residual vs. standardized predicted value plots.

To determine which factors were significant predictors of passenger WTF on autonomous aircraft, a backward stepwise regression analysis was performed on the data set. Table 1 provides descriptive statistics for all model variables.

**Table 1**
Scale variables and descriptive statistics for participants in stage 1 (n = 522).

| | M | SD |
|---|---|---|
| Complexity | .67 | .86 |
| Familiarity | -.65 | .94 |
| Value | .41 | .86 |
| Fun Factor | .23 | 1.03 |
| Wariness of New Technology | -.57 | .92 |
| Anger | 3.57 | 2.90 |
| Disgust | 3.37 | 2.90 |
| Fear | 5.29 | 3.31 |
| Happiness | 4.95 | 2.91 |
| Sadness | 4.31 | 3.20 |
| Surprise | 6.35 | 2.69 |
| Age | 37.25 | 10.98 |
| Frequency of Travel | 3.50 | 9.98 |
| Number of Family Members | 1.35 | 1.30 |
| Income | 56,011.92 | 95,820.21 |
| Willingness to Fly | -.18 | 1.20 |

Backward stepwise regression was chosen as the statistical analysis due to the exploratory nature of the study. The results of the analysis revealed 7 items that significantly influenced WTF in this scenario. The following regression equation was generated:

$$Y = -.276 + .073X_1 + .332X_2 - .076X_3 - .105X_4 + .150X_5 - .005X_6 + .155X_7$$

Where Y represents the predicted score of passenger WTF in autonomous aircraft, and $X_1$ through $X_7$ represent the factors of familiarity, fun factor, wariness, the emotion of fear, the emotion of happiness, age, and education level (Graduate degrees). The results indicated that 73.70% (73.40% adjusted) of the variance in WTF in autonomous aircraft was accounted for by the overall model. This model was statistically significant with $F$ (7,514) = 205.98, $p$ < .001. Fig. 2 depicts the significant predictors, and Tables 2 and 3 provide regression analyses and model summary, respectively.

### 3.2. Stage 2

An independent second sample was used in stage 2 to validate the regression analysis conducted in stage 1. Model fit, and thus validity, was tested by conducted three different statistical procedures. These procedures were a cross-validated $R^2$, a bivariate correlation, and a $t$-test between actual willingness scores from the second sample and the predicted scores obtained by applying the regression equation created in stage 1 to the data on the second sample.

The purpose of conducting a $t$-test as described above between actual and predicted scores is to illustrate that there is not a significant difference between the sets of data. The results of this test did, in fact, reveal a statistically insignificant difference where $t$ (1038) = −0.381,

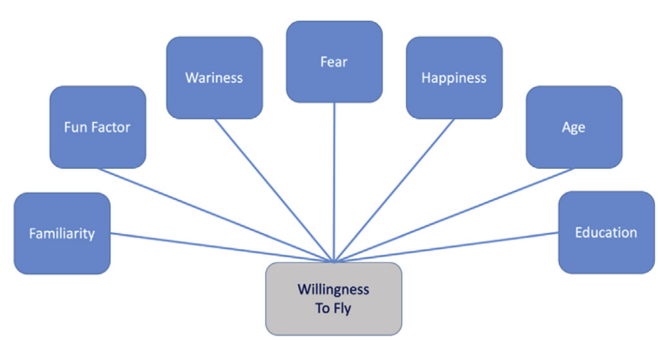


**Fig. 2.** Seven significant predictors were identified of willingness to fly: familiarity, fun factor, wariness of new technology, fear, happiness, age, and education level (graduate degrees).

**Table 2**
Summary of regression analyses for variables Predicting willingness to fly on board an autonomous commercial airliner (N = 522) from Stage 1. A backward stepwise regression was used due to the exploratory nature of the study. The data indicates those participants who were most willing to fly were ones who were familiar with the concepts, believed them to be fun, felt happiness toward the concepts, and held graduate degrees. Participants who reported wariness toward new technology, were fearful, and older were less willing to fly.

| Variable | B | SE | t | Sig. |
|---|---|---|---|---|
| Constant | -.276 | .157 | −1.753 | .080 |
| Familiarity | .073 | .034 | 2.142 | .033 |
| Fun Factor | .332 | .037 | 9.082 | .000 |
| Wariness | -.076 | .033 | −2.287 | .023 |
| Fear | -.105 | .012 | −9.060 | .000 |
| Happiness | .150 | .014 | 10.418 | .000 |
| Age | -.005 | .003 | −2.005 | .045 |
| Education Level (Graduate Degrees) | .155 | .072 | 2.141 | .033 |

**Table 3**
Summary Stage 1 Model (N = 522).

| $R^2$ | Adjusted $R^2$ | df | F | Sig. |
|---|---|---|---|---|
| .737 | .734 | 7514 | 205.98 | .000 |

$p$ = .703. The findings of this model fit test suggest support for the claim of the validity of the model, and statistical value are depicted in Table 4.

Following this, a bivariate correlation analysis was performed to show the similarity between the actual and predicted scores as described previously. The findings from this analysis revealed a statistically correlation, where $r$ (518) = 0.823, $p < .0001$. Showing a strong correlation between predicted and actual scores which again adds support to the validity of the prediction model created. Correlation statistical values are displayed in Table 5.

Finally, the model fit was also tested using a test for cross-validated $R^2$. Cross-validated $R'^2 = 1 - (1 - R^2)[(n + k)/(n\text{-}k)]$, where $R^2$ is overall $R^2$ from the initial model, n is the sample size of the stage 1 sample, and k is the degrees of freedom. A cross-validated $R^2$ determines the applicability of a model to the independent samples from the same population and the population as a whole. This test revealed $R'^2 = 0.729$. Due to the similarity between the initial $R^2$ and the cross-validated $R^2$, model fit can be inferred.

## 4. General discussion

The purpose of this study was to develop and validate a predictive model to identify the significant factors which would predict a person's WTF aboard an autonomous aircraft. Prior studies have experimentally investigated the effect of variables such as gender, nationality, weather, number of pilots related to WTF (Mehta et al., 2017; Ragbir et al. 2018; Rice et al., 2014; Rice and Winter 2015; Winter et al., 2015), but no prior study for which we are aware has developed a predictive model. Current findings from this study indicate seven significant predictors of WTF, which accounted for 73% of the variance in the overall model.

Some industries have seen high levels of automation increase within the last three decades (Hoff and Bashir, 2015), especially in the medical and aviation fields. Within the aviation industry, there is also a growing concern for an upcoming pilot shortage (Hemmerdinger, 2018). As a result, one possible solution may be the use of more automation or even the pursuit of autonomous aircraft to reduce or remove an onboard pilot. However, in this event, it is important to understand the types of characteristics for which consumers may be willing to fly on-board autonomous airliners.

Three of the seven significant predictors were familiarity with autonomous flight, fun factor, and happiness. The predictor of familiarity is particularly an interesting one because many consumers are currently unaware of the high levels of automation that exists even in current commercial airliners. As their knowledge and familiarity with the use of automation increases, it is logical that they would be more willing to fly as they may few an autonomous aircraft as a natural extension of the current automation offered onboard a commercial aircraft. As found by Karvonen (2001) consumer's trust varied by a simple or more complex design, with consumers being less trusting of the more complex design. As familiarity increases, the consumer's view of the complexity may decrease leading to more trust and willingness. Similar to familiarity, as the participant's rating of fun factor increased so did their WTF. The positive relationship between the fun factor and WTF makes sense as those individuals who would rate the experience as fun should be more willing to fly onboard the aircraft. This may also relate to the emotional response of happiness. Prior research has demonstrated the heightened role that the affective domain plays in decision-making (George, 1991; Kahneman et al., 1982; Wright and Bower, 1992), especially when those decisions need to be made fairly quickly or in the absence of a lot of information (Kardes et al., 2004; Loewenstein and Lerner, 2003). Therefore, as a participant's happiness increases so does their WTF onboard an autonomous aircraft.

For those participants who expressed wariness toward new technology, their WTF decreased. Similarly, those who felt fear towards the idea of an autonomous airliner were less willing to fly. Somewhat opposite to familiarity, those participants who may view autonomous aircraft as extremely complicated and complex will likely be unwilling to fly on them (Karvonen, 2001). This technology would also be very new to the airline environment, and for some consumer's the thought of having no pilot on-board to take over in an emergency could be one possible area of fear. Another possible consideration could be related to their thoughts on quality. If they are unsure of the technology or concept of an autonomous aircraft, this questionable quality could result in a decreased WTF (Hughes et al., 2009).

Finally, the predictors of education level and age were significantly related to WTF. Those participants who had a graduate degree were

**Table 5**
Correlation analysis actual vs. predicted scores.

| | | Actual | Predicted |
|---|---|---|---|
| Actual | Pearson Correlation | 1 | .823 |
| | Sig | | .000 |
| | N | 520 | 520 |
| Predicted | Pearson Correlation | .823 | 1 |
| | Sig | .000 | |
| | N | 520 | 520 |

**Table 4**
T-test between actual and predicted scores.

| | Levene's Test for Equality of Variances | | *t*-test for Equality of Means | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | F | Sig. | t | df | Sig. | Mean Diff. | Std. Error Diff. | 95% Confidence Interval | |
| | | | | | | | | Lower | Upper |
| Equal Variances Assumed | 16.855 | .000 | -.381 | 1038 | .703 | -.026 | .068 | -.15948 | .1076 |

more willing to fly than participants who only had a high school degree or a bachelor's degree. It is possible that as participant's education level increases their either become more familiar with technology or also experience a decrease in their wariness of new technology. If education level results in participants viewing the system as less complex, it is possible that they will be more willing to fly (Karvonen, 2001). While age was also a significant predictor, it is acknowledged that the beta weight was very small so while it appears younger individuals may be more willing to fly on autonomous airlines, this is an area that warrants further investigation.

### 4.1. Practical application

The findings from this study provide valuable insight into the factors that identify which types of persons may be most willing to fly onboard autonomous airliners. As the technology continues to be developed in this field for aircraft of all sizes, a major component to the success or failure of this technology will be consumer buy-in. The use of a model which may help identify those consumers who would be most willing to fly could help identify the early adopters who would be willing to conduct the experience. It also identifies factors such as fear and wariness, which may be compensated for through the use of education, examples, and experiences where consumers could become more familiar with the devices before conducting a flight onboard one. It is important that as the technology advances, efforts are also made to inform and encourage consumer buy-in and acceptance simultaneously. This model offers practical insights into which consumers may be the most likely to support this technology.

### 4.2. Limitations

The current study has some limitations to be discussed. First, the sample was one of convenience and selected from Amazon's ® Mechanical Turk ® (MTurk). While prior studies (Buhrmester et al., 2011; Germine et al., 2012; Paolacci et al., 2010; Rice et al., 2017) have demonstrated the validity of using data from this source and found it as reliable as traditional laboratory data, the results are limited in their generalizability to those types of individuals who complete online human intelligence tasks. Additional research should replicate this study using broader populations to examine the fit of the model to increase the generalizability of the findings from this current study.

Second, it is recognized that the study is limited through the collection of attitudinal data using a hypothetical scenario. The findings represent the attitudes that consumers have to predict their WTF in autonomous aircraft. It is recognized that while research indicates attitudes tend to accurately predict behaviors (Ajzen, 1985; Ajzen and Driver, 1992), it is possible that in the actual event that a consumer could fly on an autonomous aircraft, the factors that predict their willingness could shift. However, given that there are currently no easily accessible autonomous aircraft, a behavioral investigation is not currently achievable. It is also acknowledged that there are limitations to the use of a hypothetical scenario. The design of the scenario was carefully crafted to balance the tradeoffs between specific and vague descriptions. Ultimately, the scenario in the current study was one with more vague descriptions. The rationale for this was based on the use of similar scenarios in previously published studies (Winter et al., 2015), and also a limitation to using a very specific scenario would be restrictions to the generalizability of the findings (e.g., only application to that specific vehicle or manufacturer). It is recognized that different scenarios may produce different results, and further research should investigate the influence of the scenario on willingness to fly.

Lastly, the exploratory nature of this study was limited to the 20 possible predictors identified by the researchers for use in this study. As further research is conducted on consumer's WTF on autonomous aircraft, it is possible that new predictors may be identified for inclusion in a modified or expanded model. The continuation of this area of investigation may help provide information to manufacturers and airlines on the types of consumers who will be most willing to fly on autonomous airliners.

## 5. Conclusions

The purpose of this study was to develop a predictive model to identify which factors would significantly predict consumer's WTF onboard an autonomous commercial airliner. Prior studies have examined this concept through an experimental lens, but no prior study for which we are aware has developed a predictive model. The study was conducted using over one thousand participants and found that seven factors were significant predictors of WTF: familiarity with autonomous flight, fun factor, general wariness of new technology, age, education level, fear, and happiness. These seven predictors accounted for 73% of the variance explained by the overall model, and the findings indicated a good model fit. The results of this help to determine which types of consumers may be most willing to fly onboard an autonomous airliner and may offer insight to the industry as this technology continues to be developed and deployed around the world. The data provides insights into those participants who were most willing to fly. Participants who are familiar with the concepts, believe them to be fun, feel happiness toward the concepts, and possess graduate degrees are, in general, willing to fly. Participants who report wariness toward new technology, are fearful, and older are, in general, less willing to fly.

## Appendix C. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jairtraman.2018.12.008.

## Appendix A. Willingness to fly scale (Rice et al., 2015)

| | | | | |
|---|---|---|---|---|
| 1) I would be happy to fly in this situation | | | | |
| Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| 2) I would be willing to fly in this situation | | | | |
| Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| 3) I have no fears of flying in this situation | | | | |
| Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| 4) I would be comfortable flying in this situation | | | | |
| Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| 5) I would have no problem flying in this situation | | | | |
| Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| 6) I feel confident flying in this situation | | | | |
| Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| 7) I would feel safe flying in this situation | | | | |
| Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |

## Appendix B

*Complexity Perception Scale*. A five-statement Likert-scale was developed with ratings from strongly agree (2) to strongly disagree (−2), with a neutral option of 0. The statements were: a) The automation that controls autonomous commercial airplanes is very complex; b) I do not understand the automation that controls autonomous commercial airplanes; c) It is difficult to know how the automation that controls autonomous commercial airplanes works; d) I have no idea what the automation that controls autonomous commercial airplanes is doing; and e) It is a mystery to me how the automation that controls autonomous commercial airplanes operates.

For validation, a factor analysis using the principle components and varimax rotation demonstrated that all items loaded onto one factor. A Cronbach's Alpha was performed to examine for internal consistency and resulted in a value of 0.84 while Guttman's split-half tests demonstrated a coefficient of 0.82 indicating high reliability (Field, 2013).

*Familiarity Scale.* A five-statement Likert-scale was developed with ratings from strongly agree (2) to strongly disagree (−2), with a neutral option of 0. The statements of the familiarity scale were: a) I am familiar with; b) I have a lot of knowledge about autonomous commercial airplanes; c) I have read a lot about autonomous commercial airplanes; d) Autonomous commercial airplanes have been of interest to me for a while; and e) I know more about autonomous commercial airplanes than the average person.

For validation, a factor analysis using the principle components and varimax rotation demonstrated that all items loaded onto one factor. A Cronbach's Alpha was performed to examine for internal consistency and resulted in a value of 0.84 while Guttman's split-half tests demonstrated a coefficient of 0.78 indicating high reliability (Field, 2013).

*Value Scale.* A five-statement Likert-scale was developed with ratings from strongly agree (2) to strongly disagree (−2), with a neutral option of 0. The statements on this scale were: a) An autonomous commercial airplanes is something that would be beneficial to me; b) autonomous commercial airplanes would be something valuable for me to own; c) I think autonomous commercial airplane technology is useful; d) There would be value in using an autonomous commercial airplane; and e) If autonomous commercial airplanes were available, I think it would be beneficial to own one.

For validation, a factor analysis using the principle components and varimax rotation demonstrated that all items loaded onto one factor. A Cronbach's Alpha was performed to examine for internal consistency and resulted in a value of 0.96 while Guttman's split-half tests demonstrated a coefficient of 0.92 indicating high reliability (Field, 2013).

*Fun Factor Scale.* A five-statement Likert-scale was developed with ratings from strongly agree (2) to strongly disagree (−2), with a neutral option of 0. The statements on this scale were: a) I like the idea of autonomous commercial airplanes; b) I think it would be fun to ride in an autonomous commercial airplane; c) I am interested in trying out an autonomous commercial airplane; d) I think it would be cool to have an autonomous commercial airplane; and e) I've always wanted to ride in an autonomous commercial airplane.

For validation, a factor analysis using the principle components and varimax rotation demonstrated that all items loaded onto one factor. A Cronbach's Alpha was performed to examine for internal consistency and resulted in a value of 0.95 while Guttman's split-half tests demonstrated a coefficient of 0.90 indicating high reliability (Field, 2013).

*Wariness of New Technology Scale.* A five-statement Likert-scale was developed with ratings from strongly agree (2) to strongly disagree (−2), with a neutral option of 0. The statements on this scale were: a) In general, I am wary of new technology; b) New technology scares me; c) New technology is not as safe as it should be; d) I tend to fear new technology until it is proven to be safe; and e) New technology is likely to be dangerous.

For validation, a factor analysis using the principle components and varimax rotation demonstrated that all items loaded onto one factor. A Cronbach's Alpha was performed to examine for internal consistency and resulted in a value of 0.88 while Guttman's split-half tests demonstrated a coefficient of 0.85 indicating high reliability (Field, 2013).

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