Understanding the Effect of Age on Alcohol Craving in Patients with Alcohol Use Disorder:

An Exploration of a Virtual Reality Measurement of Craving

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Abstract

Background: The misuse of alcohol can result in detrimental consequences on the personal and societal level, and it is one of the main causes of preventable death. Alcohol use disorder (AUD) describes one of the main psychiatric disorders that can result in bodily and psychological damages. A construct that is of importance in the continuation of addiction is alcohol craving, an unmanageable urge to drink alcohol (Kavanagh et al., 2013). Although various studies investigated age as an influencing variable of craving, the existing literature remains contradictory. While previous studies often relied on questionnaires assessing craving the present study included Virtual Reality (VR) to measure momentous levels of craving as induced by VR environments. The present study aimed to identify whether age moderates the relationship of participants' level of general and cue-induced craving. *Method:* The study incorporated a cross-sectional design. 67 participants from the Hospital Clinic of Barcelona took part in the study. Participants were exposed to four alcohol related VR environments (Bar, Pub, Restaurant, Home). Momentary levels of craving were measured by means of a Visual Analogue Scale (VAS) and compared to participants general craving measured by the Multidimensional Alcohol Craving Scale (MACS). For the analyses, age had been converted into a dichotomous variable (young: <45, old: >45). *Results:* Age has not been found to moderate the relationship between general craving and cue-induced craving consistently over the four VR environments. Higher levels of general craving have been found to result in higher levels of cue-induced craving. *Discussion:* Compared to previous research, the results on the effect of age have been based on a more profound and up-to-date statistical analysis. Additionally, the inclusion of VR represents an ecologically valid and momentous assessment instrument of craving. The connection of general and cue-induced craving should be implemented in treatment as momentary levels of craving have been found to influence hazardous drinking behaviours (Wray et al., 2014). As a result, future research should focus on the implementation of VR in the assessment of craving and further include physical measurements to offer an even more objective assessment of momentary craving.

Keywords: Age, Alcohol Use Disorder, Assessment, Craving, Virtual Reality

Introduction

The consumption of alcohol has significant consequences at a personal and societal level worldwide. According to the National Institute of Health (NIH), globally three million deaths a year are related to the misuse of alcohol and in the United States alcohol is the "third-leading preventable cause of death" (NIH, 2021). Alcohol use disorder (AUD) is one of the most prevalent psychiatric disorders (Witkiewitz et al., 2019). It is characterised by destructive impacts on one's body e.g. the alcoholic liver disease, cancer or neurological problems (Agabio et al., 2017). Additionally, AUD can lead to various psychological consequences including behavioural problems and psychosocial impairments (Hicks et al., 2010; Foster et al., 2014). Similarly, AUD is highly comorbid with various psychological disorders including mood and anxiety disorders (Grant et al., 2004) but also with psychotic disorders (Castillo-Carniglia et al., 2019). Likewise, the consumption can lead to multiple problems including low inhibitory control regarding drinking or continuation of drinking patterns (Witkiewitz et al., 2019). However, not only the lives of individuals diagnosed with AUD are influenced detrimentally but also their social environment. Studies discovered a lower workplace engagement, increased rates of criminality, and a higher possibility of causing accidents as being some of the social consequences patients' alcohol misuse can result in (Witkiewitz et al., 2019). The consequences AUD can have for affected individuals as well as for their social environment illustrate the harmful impact of this psychiatric disorder. Thus, the need for a proper investigation of AUD is given to generate adequate help for the individuals in need.

Despite the negative impact of AUD on the personal and societal level, only a limited number of affected people seek professional help or assistance. The low rate for professional help can have different origins ranging from underrating one's alcohol intake (Kerr & Stockwell, 2011), the fear of being stigmatized (Keyes et al., 2010), sex differences, or the existence of comorbid psychiatric disorders (Rim et al., 2021). In comparison, while some people manage to cease alcohol drinking without professional help, others seeking help show different patterns of recovery, ranging from a one-time successful treatment outcome to recurrent relapses over many years (Tuithof et al., 2014; Sliedrecht et al., 2019). A study by Andersson et al. (2019) found a relapse rate of 44% in the first three months after treatment discharge showing that a successful treatment is by no means guaranteed. Regarding the contradictory treatment outcomes, the present study will focus on individuals seeking professional help to offer scientical ground for effective treatments.

Many factors have been depicted that play a significant role in relapse management. These factors can, for example, be of biological nature like age, genetics or sleep quality (Sliedrecht et al., 2019). But relapse rates were also found to be higher for people with psychiatric comorbidities like the attention deficit hyperactivity disorder (ADHD) (Sliedrecht et al., 2019). Another strong factor for relapse is alcohol craving (Stohs et al., 2019). Noticeable results for the effect of craving have also been found on the severity of alcohol misuse and drinking patterns in general (Wapp et al., 2013; Ghiţă & Gutiérrez-Maldonado, 2018). Research also suggests that a reduction of craving should play a substantial role in AUD treatment (O'Brien, 2005). The systematic review of Sliedrecht et al. (2019) underlines that various components that have been hypothesized to have an influencing role on maintaining AUD have been widely examined within the literature. Nevertheless, the relationship between several constructs and AUD remains contradictory. Many studies also show significant shortcomings disallowing concrete conclusions on the actual interaction. This inconsistency in outcomes holds also true for alcohol craving (Tolliver et al., 2010; Hernández-Serrano et al., 2021). Regarding the negative outcomes of an excessive alcohol misuse, it is important to understand the mechanisms behind the development and maintenance of AUD, especially in regard to developing a holistic approach in terms of assessment and treatment options.

Alcohol Craving

Alcohol craving has often been identified as a strong underlying mechanism in terms of AUD, relapse rates and the severity of alcohol misuse. Alcohol craving is described as a strong and uncontrollable urge to drink alcohol and if not satisfied it can result in psychological and physiological distress (Addolorato et al., 2005; Kavanagh et al., 2013). Various components have been identified to play a critical role with regard to the intensity of craving perception in people diagnosed with AUD. Studies indicate an effect of sociodemographic factors such as age and gender but also of clinical influences like stress or the severity of AUD (Hernández-Serrano et al., 2021). Hereby higher momentary levels of craving were associated with a lower age, the female gender, and higher stress levels (Hernández-Serrano et al., 2021). Yet, other studies came to different conclusions resulting in mixed results for the impact of distinct constructs including age and gender on alcohol craving (Tolliver et al., 2010). These inconsistencies in terms of predictors of craving do not allow for a proper understanding of potential influencing factors nor do they allow to draw conclusions in terms of reasonable treatment options.

Age and Craving

Sociodemographic variables have been investigated with regard to the connection to alcohol consumption, misuse, and craving. Hereby extensive research attempted to understand and find a solid causal relationship between age and craving. As an example, Keyes et al. (2012) and Papachristou et al. (2013) investigated the consequences of an early onset of AUD and concluded that it is related to craving. Moreover, starting to drink at an early age often coincides with heavier drinking and other obstacles related to alcohol intake (Morean et al., 2018). Besides the age at onset, an impact of age in general was supported by a study suggesting a decrease of alcohol craving with increasing age (Hintzen et al., 2011). While these investigations highlight age as a predicting variable regarding alcohol intake, severity and craving, other studies could not confirm this connection. Wapp et al. (2013) examined whether age, next to other constructs, was associated with alcohol craving showing no significant relationship. Similarly, a study by Hernández-Serrano et al. (2020) could not identify age as a predictor of change in alcohol craving. On that account, while various studies emphasize age as an important predictor of alcohol craving, the results are not consistent, and more research is needed to investigate this potential correlation.

The Role of Assessment Instruments

The mixed results on the relationship between age and craving raise the question where this inconsistency stems from. A potential factor for inconclusive outcomes can be the selected assessment instrument (Drobes & Thomas, 1999). Different evaluations often defined and thus measured craving differently. Additionally, as craving cannot be understood as a constant state, different circumstances, like mood or perceived availability of alcohol, can influence the craving experience as well (Rosenberg, 2009). Furthermore, different measurement approaches have been found to show unequal outcomes regarding predictors of alcohol craving. A study by Hernández-Serrano et al. (2020) did not identify sociodemographic factors like age or gender as reasonable predictors of change in alcohol craving as measured by means of a cue-exposure technique including Virtual Reality (VR). On the contrary, a paper-pencil-based study by Chakravorty et al. (2010) found a decrease of craving with increased age. These inconsistencies and the potential implicit effect of assessment instruments needs to be further studied. To be able to have reliable treatment possibilities and suitable professional assistance it is crucial to have unambiguous information on predictors of craving.

Cue-Exposure Paradigm

There is a growing body of literature in terms of craving assessment in the field of addictions. These include self-reported subjective levels of alcohol craving (e.g. paper and pencil instruments) (Sayette et al., 2000; Kavanagh et al., 2013), psychophysiological variables (e.g. heart rate variability or skin conductance – Sayette et al., 2000) or neurophysiological correlates (e.g. functional magnetic resonance imaging – Elkins et al., 2017). A central technique to explore different dimensions of craving is based on the cue-exposure paradigm. Compared to questionnaires, the cue-exposure paradigm allows to assess momentary levels of craving as the patients can be exposed to beverages or contexts that elicit alcohol craving (Vollstädt-Klein et al., 2011). An additional asset is the possibility to combine cue-exposure with e.g. neurochemical measurements, an electroencephalogram (EEG) or psychophysiological instruments like eye tracking or skin conductance (Drummond & Glautier, 1994; Miranda et al. 2008) which can add more objective information to self-report measurements. Consequently, cue-exposure offers a more comprehensive measurement of craving.

The cue-exposure technique involves exposure to relevant alcohol-related stimuli with the aim to elicit a cognitive-emotional-physiological and behavioural response pattern in individuals with AUD (Mellentin et al., 2017). The ultimate goal of cue-exposure is to trigger alcohol craving as part of assessment or treatment protocols (Mellentin et al., 2017). This can take place *in vivo,* in clinical settings, or by the use of multimedia and it can also include contexts related to alcohol intake. Cue-exposure is based on classical conditioning. Hereby it is assumed that previous neutral contexts will be associated with the drug-induced effect and various stimuli, or situations can lead to alcohol cravings or other conditioned responses which often result in drinking behaviours (Bordnick et al., 2008; Vollstädt-Klein et al., 2011; Mellentin et al., 2017; Hernández-Serrano et al., 2021). The method of cue-exposure has been extensively used to sensitize people diagnosed with AUD with contexts that are prone to elicit alcohol craving to reduce responses to craving and ultimately to enhance people's resilience towards alcohol-cues (Vollstädt-Klein et al., 2011; Ghiţă & Gutiérrez-Maldanado, 2018). Nevertheless, research indicated limited impacts in studies using this paradigm due to "simplistic and limited stimuli inputs" (Hernández-Serrano et al., 2021). Accordingly, clear results with regard to understanding craving patterns require a more comprehensive approach of cue-exposure that can include a variety of cues such as social, drinking and mood settings (Bordnick et al., 2008).

Virtual Reality

A technology that can enhance cue-exposure techniques is VR. By means of technological applications, VR offers a 3D simulation of a real-life context "by presenting a diverse range of stimuli to create a fully immersive experience" (Ghiţă & Gutiérrez-Maldanado, 2018). The sensory inputs can range from auditory over visual to tactile inputs and reconstruct real-life experiences and perceptions (Ghiţă et al., 2021). In the context of AUD, triggering cues are especially important in eliciting craving (Bordnick et al., 2008; Ghiţă et al., 2021). VR offers a safe environment that is able to imitate real life situations that are known to evoke alcohol craving but without triggering actual drinking behaviours and thus provoking relapse (Hone-Blanchet et al., 2014). Studies incorporating VR-cue-exposure into the therapeutic setting of treating AUD (Durl et al., 2018; Hernández-Serrano et al., 2020) and evoking alcohol cravings (Bordnick et al., 2008; Ryan et al., 2010) have supported the use of VR with significant outcomes also regarding long-term success. Hence, as VR offers a more subjective and realistic experience it has a widely demonstrated success in eliciting craving and in treating AUD. VR can therefore be regarded as an improvement of cue-exposure techniques and it can offer a generalisability to the real world.

The Present Study

As previous studies ascribe a strong impact to craving regarding drinking patterns and relapse rates in patients with AUD (Wapp et al., 2013; Ghiţă & Gutiérrez-Maldonado, 2018; Stohs et al., 2019) it is necessary to have clear results on the determinants for craving. As demonstrated earlier, there are inconsistent outcomes across different studies regarding age as a predicting factor of alcohol craving using traditional assessment measurements (e.g. questionnaires) and cue-exposure techniques. Therefore, the current initiative aims to explore whether age acts as a moderator between general craving and cue-induced craving experienced during VR exposure. Based on the findings from previous research the present study aims to answer whether age moderates between general craving as measured by the Multidimensional Alcohol Craving Scale (MACS, Serecigni et al., 2004) and craving as induced by four different VR environments (measured via the Visual Analog Scales for Craving, VAS-C, Ghiţă et al., 2021). The four environments (pub, restaurant, bar and home) were created because they had been found to elicit high levels of craving (Hernández-Serrano et al., 2020). As the environments all included different features such as daytime or nighttime or the presence of social interactions the present study will examine the differences in elicited alcohol craving for the four environments. See Figure 1 for a visual representation of the investigated relationship of the three constructs.

Figure 1

Representation of the Investigated Moderation Effect of Age on Alcohol Craving.
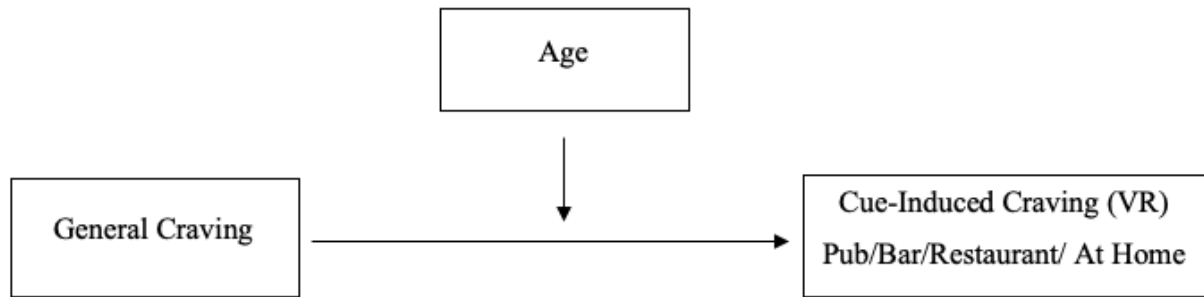
Note. General Craving represents craving as measured by the MACS questionnaire and Cue-Induced Craving (VR) represents craving as evoked by the different VR environments and as measured by the VAS-C assessing craving experienced after using the VR environment.

Method

Design

This study was based on the concluded project "ALCO-VR" conducted at the University of Barcelona in collaboration with the Addictive Behaviors Unit from the Hospital Clinic of Barcelona. The present study was based on the assessment session of the project. The research was descriptive in nature incorporating a cross-sectional design. The studied variables included participants age, the general level of craving measured by the MACS and cue-induced craving measured using the VAS-C after participants were exposed to the four different VR environments (pub, bar, home and restaurant). Hereby, age was studied as a moderator variable and the MACS results acted as the independent variable with the results from the VAS-C resulting in four dependent variables. The study was performed in accordance with the Declaration of Helsinki (World Medical Association, 2001) and ethical approval was obtained from the Ethics Committees at the University of Barcelona and Hospital Clinic of Barcelona in Spain [ethical code number was 0377 (HCB/2017/0377) and the approval date was 09/2017].

Participants

The sample consisted of 67 participants who were recruited from the Hospital Clinic in Barcelona. All patients provided written informed consent to participate in the study. The following inclusion criteria had to be met by the patients to take part in the study: Participants had to be older than 18 and at the moment of the study they had to be diagnosed with a moderate to severe AUD as stated in the *Diagnostic and Statistical Manual of Mental Disorders* (5th ed.; DSM-5; American Psychiatric Association, APA, 2013). Additionally, patients must be regarded as resistant to treatment as usual (TAU) meaning that they

experienced at least one relapse, describing a return to habitual drinking patterns, within six month after they received treatment (treatment was administered at the Hospital Clinic of Barcelona). Lastly, before the start of the first session, participants had to abstain alcohol for at least three days.

Next to the inclusion criteria, several exclusion criteria had been predefined. Patients displaying severe cognitive impairments were not included as well as people who had been diagnosed with severe psychopathology (e.g., major depressive disorder, schizophrenia) or neurodegenerative disorders (e.g., dementia). Additionally, individuals with a comorbid opioid use disorder were excluded as the neuropaths of opioid and alcohol misuse are similar (Hood et al., 2020). Due to the use of VR, people with severe visual impairments, epilepsy or pregnancy could not be included. Lastly, no anti-craving medication was accepted (Hernández-Serrano et al., 2020). The occasional use of nicotine and other illicit drugs (except opioids) was expected to be not interfering with the study. The descriptive statistics of the participants can be found in Table 1 in the results section.

Materials

Identification of Alcohol Use Disorder (AUDIT)

To identify the level of alcohol consumption and participants drinking behaviours the self-report measurement Alcohol Use Disorder Identification Task (AUDIT) was implemented. The AUDIT consists of 10 items measuring alcohol intake, dependency and negative consequences (Reinert & Allen, 2002). The sum score of the items ranging from 0 to 40 indicates whether a potential alcohol problem exists with the cut-off score being 8 and higher scores indicating more severe alcohol problems. As demonstrated by Reinert and Allen (2002) the questionnaire shows a good internal consistency.

Questionnaire Assessing Craving (MACS)

To assess the extent of general craving the Multidimensional Alcohol Craving Scale (MACS) was used. The scale consists of 12 items adopting a 5-point Likert Scale ranging from 1 being 'strongly disagree' to 5 being 'strongly agree'. Additionally, the measurement includes two subscales, 'desire to drink' and 'behavioural inhibition' with the sum of both resulting in the overall craving score. craving is then classified as non-existing (0-12), mild (13-22), moderate (23-40) or intense (>40). Overall, the MACS shows good psychometric properties with an excellent internal consistency ($\alpha = 0.94$) resulting in a valid measurement of craving (Serecigni et al., 2004).

Virtual Reality Assessment (VAS-C)

To measure the momentary level of alcohol craving as induced by the VR environments the single item measurement VAS-C was used. The VAS-C as a self-report measurement had been integrated within the VR software to measure the subjective and momentary experience of craving (Bordnick et al., 2008). Scores ranged from 0 indicating no craving to 100 indicating an intense craving experience. The VAS allows to gain real-time responses from subjects while they are exposed to the VR environments (Ghiţă & Gutiérrez-Maldonado, 2018) and various studies have used the measurement in studies incorporating VR or more traditional cue exposure techniques (Bordnick et al., 2005; Cutler, 2005).

Virtual Reality Software. The VR software included four environments (bar, pub, restaurant and home environment) and the five most preferred alcoholic beverages as selected by the participants from a list of several drinks before the start of the study. Additionally, human avatars were included to mimic social interactions and the environments were shown in different day and night times. To introduce the participants to the VR technology they have first been presented with a neutral environment (white background and glass of water). Participants then were exposed to the different environments and beverages and asked to rate each according to the momentary level of alcohol craving.

Virtual Reality Hardware. The VR equipment included an Oculus Rift S head-mounted display (HMD), sensors, touch controllers, and a computer compatible with VR technology (INTEL® Core™ i7–2,600 CPU,16.0 GB RAM, 64-bit operating system, x64 processor, and a NVIDIA GeForce GTX 1080 Ti graphic card).

Figure 2

Demonstration of the Four Different VR Environments
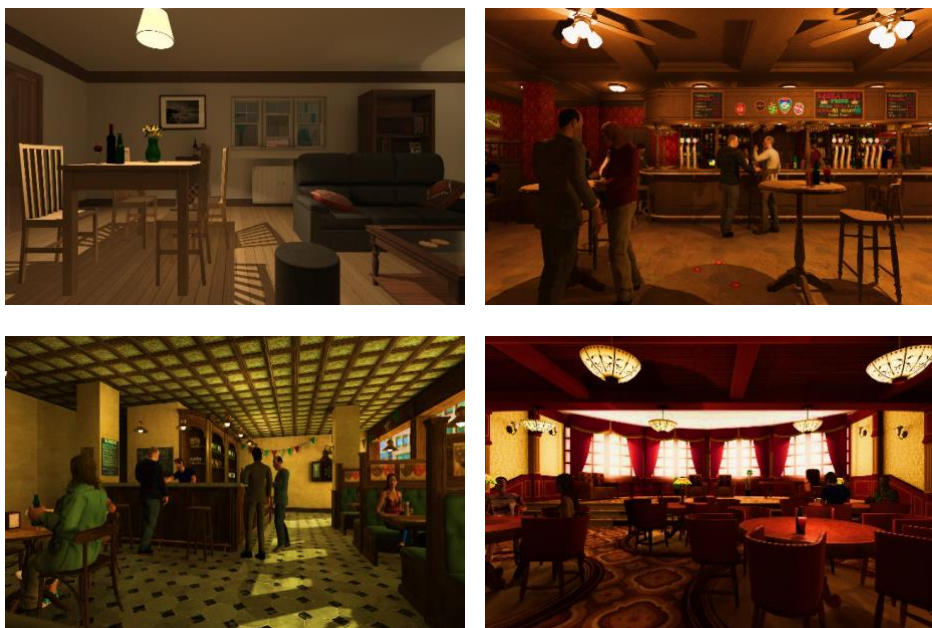
Note. The environments demonstrate from the top left to the bottom right: home environment, a pub, a bar, and a restaurant. Different daytimes have been chosen based on what patients reported to be most likely to elicit craving.

Procedure

The study invited patients diagnosed with AUD from the Hospital Clinic of Barcelona to participate in the study (based on the inclusion and exclusion criteria). All patients took part in an initial assessment to gather information on their demographics and clinical anamnesis (information on medication, psychopathologies etc.). Then, all participants answered the MACS to give information on their general craving within the last week. Hereinafter, the patients were introduced to the VR hardware through a short instruction. While being exposed to the VR environments the patients were asked via the VAS-C about their momentary craving level dependent on the drinks and environments they were exposed to. The software generated a hierarchy based on the preferred environments and alcoholic beverages. Patients spent 20 seconds in each environment. Additionally, olfactory information of the beverages presented within the VR environment was introduced to the patients by a small amount of the actual drink being presented to the participants on a cotton pad (Hernández-Serrano et al., 2021) to enhance a realistic experience.

Data Analysis

The statistics program SPSS (version 27) was used to analyse the data. For the AUDIT and for the VAS-C in general as well as for each environment mean scores were calculated to gain an impression of the overall level of general and cue-induced craving. Altogether, four moderation analyses were performed to analyse the relationship between general craving (MACS) and cue-induced craving (VAS) and whether participants age moderates the relationship in all four VR environments. Hereby, age has been set as the moderator variable and craving as measured by the MACS has been set as the independent variable. The different VR environments (pub, bar, home and restaurant) resulted in four different dependent variables. For the moderation analyses the SPSS program PROCESS macro was utilized and several regression analyses were performed. Age had been transformed into a dichotomous variable, with a younger age representing the age span of 18-45 and the older age representing the age between 46-69. The cut-off score for age has been based on a recent paper of Ghiță et al. (2021). All assumptions were checked and satisfied with the exception of normality.

Results

Descriptive Statistics

The descriptive information of the participants has been summarized in Table 1. The sample had a mean age of 51.52 (SD = 8.93) and most participants reported a moderate socioeconomic status (79.1%). Additionally, almost half of the participants were married or in a relationship (43.3%) and also 44.8 % showed a comorbid psychiatric disorder (e.g. depression, anxiety disorders or personality disorders). Likewise, 31.3% of the participants mentioned a use of other substances like cannabis or cocaine within the month prior to the study. Participants scores on the AUDIT measuring problematic drinking behaviours ranged from 0 to 38 with a mean of 16.43 (SD = 9.98). Furthermore, participants craving within one week prior to the measurement ranged from 12.00 to 49.00 with a mean craving of 24.69 (SD = 10.65). The mean cue-induced craving did not differ significantly between the four different environments. The VR environment pub elicited a mean craving of 43.86 (SD = 27.70) followed by the bar (M = 42.45, SD = 27.15), the restaurant (M = 41.02, SD = 26.47) and lastly the house environment (M = 40.64, SD = 27.49).

Table 1

Descriptive Statistics of Participants

Variables	Categories	All participants (N = 81)
Gender, N (%)	Male	42 (62.7%)
	Female	25 (37.3%)
Age, Range: M (*SD*)	Years	25-69: 51.25 (*SD* = 8.93)
N (%)	Low	14 (20.9%)
N (%)	High	53 (79.1%)
Socioeconomic Status, N	Low	12 (17.9%)
(%)	Moderate	53 (79.1%)
	High	2 (3.0%)
Civil Status, N (%)	Single	12 (17.9%)
	In a Relationship/Married	29 (43.3 %)
	Divorced/Separated	20 (29.9 %)
	Widower	5 (7.5%)

Comorbid	Generally present	30 (44.8 %)
Psychopathologies, N (%)	Depression	13 (19.4%)
	Depression + anxiety	6 (9.0%)
	Depression + anxiety + PD	2 (3.0%)
	Anxiety disorders	2 (3.0%)
	PDs	25 (37.3%)
Other Substance Use Last	Yes	21 (31.3%)
Month, N (%)	No	46 (68.7 %)

Note. The abbreviations stand for the following: Means (M), Standard Deviation (SD), Quantity (N), Percentages (%), Personality Disorders (PD) and low and high age represent the dichotomous variable age had been transformed into.

Effect of Age on Craving

The following sub-section will outline the moderation analyses. Hereby it was tested whether participants age influenced the relationship between general craving and cue-induced craving levels as measured after the exposure to the VR environments.

The VR Environment Pub

The regression model had an R^2 0.14, and the model was significant, $F(3, 63) = 3.52$, $p < .05$. A main effect for general craving ($b = 0.95$, $SE = 0.35$, $t = 2.73$, $p < .01$, *95% CI* [0.25, 1.65]) was found indicating that higher levels of general craving predicted higher levels of cue-induced craving. The effect of age was non-significant ($b = 0.95$, $SE = 19.09$, $t = -0.14$, $p = .89$, *95% CI* [-40.81, 35.47]). The interaction effect between age and general craving was also not found to be significant ($b = 0.14$, $SE = 0.71$, $t = 0.20$, $p = .85$, *95% CI* [-1.28, 1.55]). These results suggest that participants age did not significantly moderate the relationship between general craving and cue-induced craving in the pub environment. A visual presentation of the moderation effect of age can be found in Appendix A.

The VR Environment Bar

The overall model showed an R^2 of 0.13 and was significant, $F(3, 63) = 3.13$, $p < .05$. For general craving a main effect was found ($b = 0.87$, $SE = 0.34$, $t = 2.52$, $p < .05$, *95% CI* [0.18, 1.56]. Therefore, higher general craving did predict higher cue-induced craving. For age no main effect was found ($b = -3.16$, $SE = 18.86$, $t = -0.17$, $p = .87$, *95% CI* [-40.84, 34.51]). Additionally, the interaction effect was not significant either ($b = 0.19$, $SE = 0.70$, $t = 0.26$, $p = .79$, *95% CI* [-40.84, 34.51]). Therefore, age has not been found to predict higher levels of cue-induced craving and age did not significantly moderate the relationship of

craving as measured before and after the VR exposure. The moderation effect of age is visualised in Appendix B.

The VR Environment Restaurant

The model had an R^2 of 0.14 and the model was significant, $F(3, 63) = 3.40$, $p < .05$. Again, a main effect was found for general craving ($b = 0.97$, $SE = 0.33$, $t = 2.90$, $p < .01$, 95% CI [0.30, 1.63]). Therefore, higher general craving predicted higher cue-induced craving. Age ($b = 2.19$, $SE = 18.28$, $t = 0.12$, $p = .91$, 95% CI [-34.34, 38.72]) and the interaction effect ($b = -0.31$, $SE = 0.68$, $t = -0.46$, $p = .65$, 95% CI [-1.67, 1.04]) were not found to be significant. A representation of the moderation effect of age is depicted in Appendix C.

The VR Environment Home

The overall model had an R^2 of 0.15 and was significant, $F(3, 63) = 3.72$, $p < .05$. A main effect for general craving was found ($b = 0.97$, $SE = 0.34$, $t = 2.82$, $p < .01$, 95% CI [0.28, 1.66]). Hence, higher levels of general craving again did predict higher craving during VR exposure. The effect of age ($b = -5.22$, $SE = 18.86$, $t = -0.28$, $p = .78$, 95% CI [-42.91, 32.47]) and the interaction effect ($b = 0.09$, $SE = 0.70$, $t = 0.12$, $p = .90$, 95% CI [-1.31, 1.49]) were non-significant. Therefore, age did not moderate the relationship of general craving and craving experienced within VR. A figure has been added in Appendix D to illustrate the moderation of age.

Discussion

The aim of the study was to investigate the relationship between general craving and cue-induced craving as moderated by the participants' age. Cue-induced craving was evoked by means of four VR environments which have been analysed separately. The main findings indicate no moderation effect of age on craving in all four environments, but higher levels of general craving have been found to correlate with higher levels of cue-induced craving. In addition, the mean score on the AUDIT indicates an overall moderate to severe level of alcohol consumption (AUDIT, n.d.). In addition, the mean score of the MACS represents an intense level of general craving (Serecigni et al., 2004). Comparing the scores on the VAS-C, measuring the momentary levels of craving as induced by the different VR environments, it becomes apparent that all four environments elicited mild to moderate levels of craving (Ghiţă et al., 2021). Thus, the requirement of the level of AUD had been met. Additionally, as the VR environments elicited mild to moderate levels of alcohol craving, VR environments have been validated again as a promising tool to measure alcohol craving (Ghiţă et al., 2019).

Moderation Effect of Age

The present study did not identify age as being a moderating variable of the relationship between general craving and cue-induced craving. No significant effect was found for either of the four VR environments. Until today previous studies did not report consistent outcomes regarding the impact of age on craving. A potential explanation for the different outcomes might be the selected method of measurement and the statistical analysis. Just as the present study Wapp et al. (2013) did not identify age as a predicting variable of craving. The authors relied on a questionnaire measuring craving and simple regression analysis to assess the relationship. In contrast, Hernández-Serrano et al. (2020) investigated changes in craving incorporating a VR treatment. Hereby the correlation analysis did not emphasize age as a predictor of change in craving as measured via questionnaires. Likewise, McHugh et al. (2016) investigated the relationship between craving and alcohol use. In this study, the authors did not identify age as a significant covariant within the regression model.

On the contrary, there are several studies that did report a significant relationship between age and AUD patients craving level. Chakravorty et al. (2010) reported a lower alcohol craving with increasing age of participants. The authors measured craving using only a questionnaire and investigated the relationship between age and craving by means of regression analyses. Additionally, a study by Pombo et al. (2016) also used a questionnaire to assess craving and they identified an inverse relationship of craving and age based on a bivariate analysis. Although Hintzen et al. (2011) selected a different questionnaire to assess craving as the just mentioned articles, neither the statistical analysis nor the result on the relationship of craving and age differed. A more recent study by Cheng et al. (2022) used the same measurement of general alcohol craving as the present study, but not the complete set of items was used. The authors investigated the relationship of age and craving by means of a moderation analysis in which craving intensity, imagery and intrusiveness were set as the dependent variables. This study revealed a greater craving intensity and imagery among younger participants.

Taking into consideration the previously incorporated methodologies, it becomes apparent that the present study is one of the few research studies that investigated age not as a predicting but as a moderating variable of craving. While Cheng et al. (2022) investigated age as a moderating variable they did not select craving as a dependent variable but craving intensity, imagery and intrusiveness. Thus the authors measured the relationship between age and subdivisions of craving only. Noteworthy, moderation analysis allows for a thorough understanding of the construct of craving and thus allowing for a more comprehensive

understanding of underlying factors of craving. As stated by Hayes & Rockwood (2017) a moderation analysis offers a more rigorous option to evaluate not only whether an effect of one construct on another exists but to understand conditions that might have an influence on the effect. Hence, opposed to the existing research, the present study as incorporated a more contemporary and extensive statistical analysis.

General Craving and Cue-Induced Craving

Nonetheless, the results of the moderation analyses indicate a significance between general craving and cue-induced craving throughout all four VR environments. Hence, higher levels of general craving have been found to be related to higher cue-induced, and momentary levels of craving. First of all, a correlation between general craving and cue-induced craving is consistent with the idea of cue-induced craving being based upon classical conditioning (Bordnick et al., 2008). The finding supports that there is a relationship between the triggered craving response during VR and the craving experience in the past. Thus the interaction can provide a ground reflecting the efficacy of VR environments for inducing craving. Previous studies that explored VR as an assessment tool for alcohol craving also came to similar results. A study by Ryan et al. (2010) investigated craving among binge drinking and non-binge drinking students. It showed that binge drinking students reported higher levels of craving after being exposed to different alcohol-related VR environments. Additionally, Ramirez and Miranda (2014) discovered that higher drinking levels among participants predicted higher craving levels as elicited by alcohol cues. These results demonstrate a relationship between general drinking behaviours and cue elicited alcohol craving. The results of the present study thus correspond with the previous findings and add that there also seems to be a relationship between general craving and cue-induced craving.

Strengths and Limitations

The present paper is characterized by including two means of measuring alcohol craving allowing for a more realistic and extensive assessment of alcohol craving (Conklin et al., 2008; Hone-Blanchet et al., 2014). In general, the cue-exposure paradigm allows for a more objective and momentous assessment of craving compared to an assessment only relying on questionnaires. Especially VR adds the possibility of a real-life like 3D experience (Hone-Blanchet et al., 2014; Ghiţă & Gutiérrez-Maldanado, 2018). Having only a limited number of craving assessment instruments, inserting VR environments can be regarded as the novelty of this study. With the study being based on the ALCO VR project, the VR software and the environments that also have been utilised have been extensively researched and developed in collaboration with AUD patients resulting in ecologically valid VR

environments (Ghiţă et al., 2019; Hernández-Serrano et al., 2020; Ghiţă et al., 2021). A strong asset is the possibility to add different sensory inputs that support a holistic opportunity for the assessment of craving (Ghiţă et al., 2021). As the produced VR environments are strongly linked to the experiences of patients they offer a realistic experience of alcohol-related environments that elicit momentary levels of alcohol craving (Bordnick et al., 2008; Hone-Blanchet et al., 2014). Existing research already supported the usefulness of VR in craving assessment (Bordnick et al., 2008; Ryan et al., 2010) which emphasizes VR as a suitable and modern technological development craving research can benefit from. Additionally and to the best of my knowledge, this is one of the first studies exploring the causal relationship between general craving and cue-induced craving as elicited by means of VR.

Notwithstanding, this study also shows several limitations which should not be neglected with regard to the meaningfulness of this study. First of all, the transformation of age into a dichotomous variable representing younger (<45) and older aged (>45) participants did not result in an evenly distributed number of participants within each condition. Generally, the sample consisted of a higher number of older aged participants making a comparison between two same-sized groups more difficult. With regard to the generalizability of this study it must be noted that the sample only consisted of Spanish participants. As noted by Andersen et al. (2015) there are cultural differences in alcohol intake also among high-risk drinkers which might implicate that there are also differences in craving experiences. Besides, craving has only been measured by means of self-reports. Self-reports do show different disadvantages like different conceptual comprehensions of craving, a lack of specified wording, or the referral to past events (Kavanagh et al., 2013) and this can result in an inaccuracy of the given answers (Paulhus & Vazire, 2007). Hence, it is not guaranteed that the extent of perceived craving has been measured properly. Lastly, the present study did not control for different potential covariables that might also influence the results at hand. Previous studies did indicate effects of the gender (Day et al., 2014), socioeconomic status (Lasserre et al., 2022) or comorbid psychopathologies like anxiety (Cheng et al., 2022) on craving and AUD. Thus, potential influential factors have not been taken into account in the present analysis which might have affected the present results.

Considering the strengths and limitations of the present study, various implications for future research arise which can benefit a more profound investigation of the effect of age on craving. As mentioned beforehand, cue-exposure and especially VR offer new and momentous possibilities to measure craving (Bordnick et al., 2008). The possibilities to include physical measurements of craving experience during the cue-exposure have not been

included within the present study but should be considered in future research. The inclusion of physical parameters can result in a more objective measurement of craving and add more reliable information to a self-report only measurement (Miranda et al. 2008). The possibility should be considered when studying craving and its determinants as it allows to have clear indicators for craving and simultaneously offering a more reliable measurement as self-report measurements (Drummond & Glautier, 1994). Additionally, future research should ensure that when studying the effect of age that there is a more equally distributed sample of younger aged participants and older participants. The present study only had a limited number of younger aged patients and hence this small sample might have led to less reliable results (Noordzij et al., 2011). Until now the observations on the effect of age are not consistent over different studies future research should focus on a larger sample with a higher distribution in age.

Conclusion

Within the present study, higher general craving has been found to be correlated with higher cue-induced craving. Additionally, age has not been identified as a moderating variable between the two constructs. Previous research showed methodological and analytical shortcomings in the assessment of the interaction between craving and age. As the present study incorporated moderation analyses, a more profound investigation has been executed. Additionally, the novelty of the present study is the incorporation of VR as an assessment instrument of craving. Hereby VR offered a momentous and profound measurement of alcohol craving. Hence, by incorporating VR the present study might give a more realistic observation of the effect of age on craving. Future research should further utilize and evolve the possibilities of the added value of VR and include physical measurements to offer a more holistic assessment of craving that does not rely on self-reports only. Also, previous studies indicated that momentary levels of craving among other state variables can result in hazardous levels of alcohol intake (Wray et al., 2014). Thus, the results of the present study can provide a framework for understanding the predicting value of general craving on momentary levels of craving which should be taken into account in future treatment.

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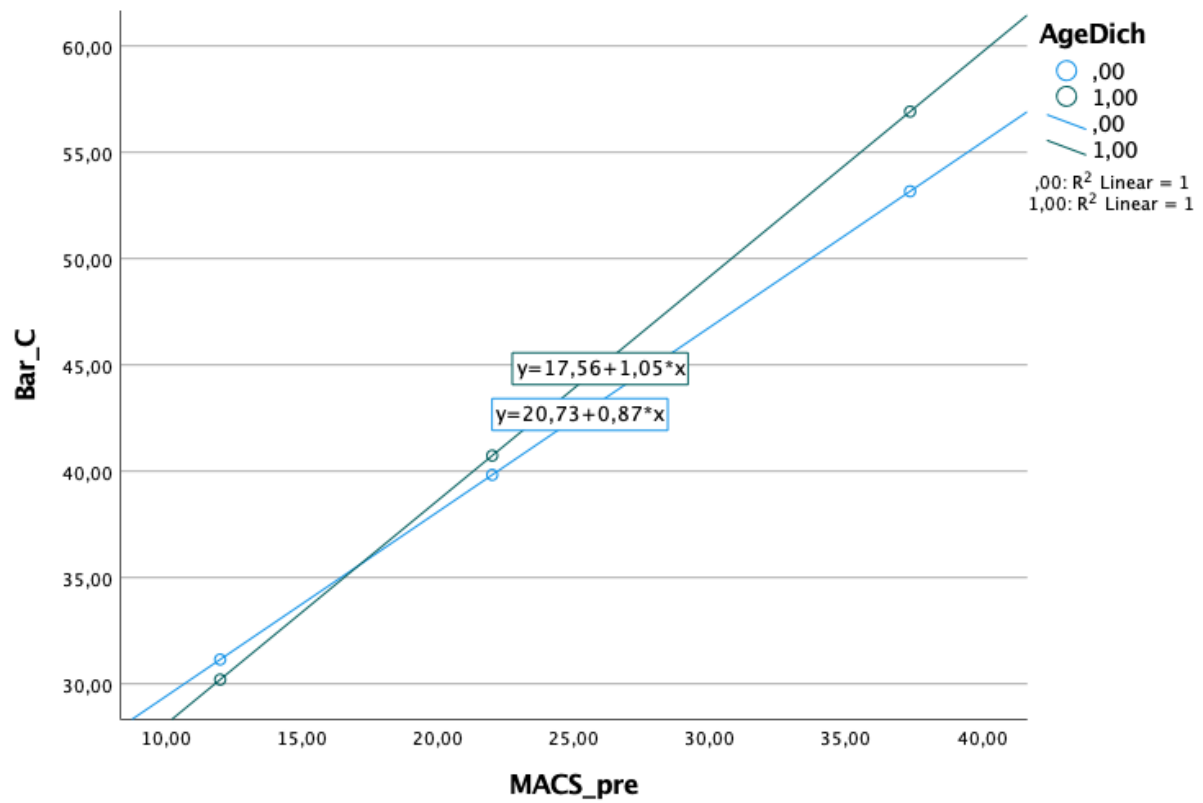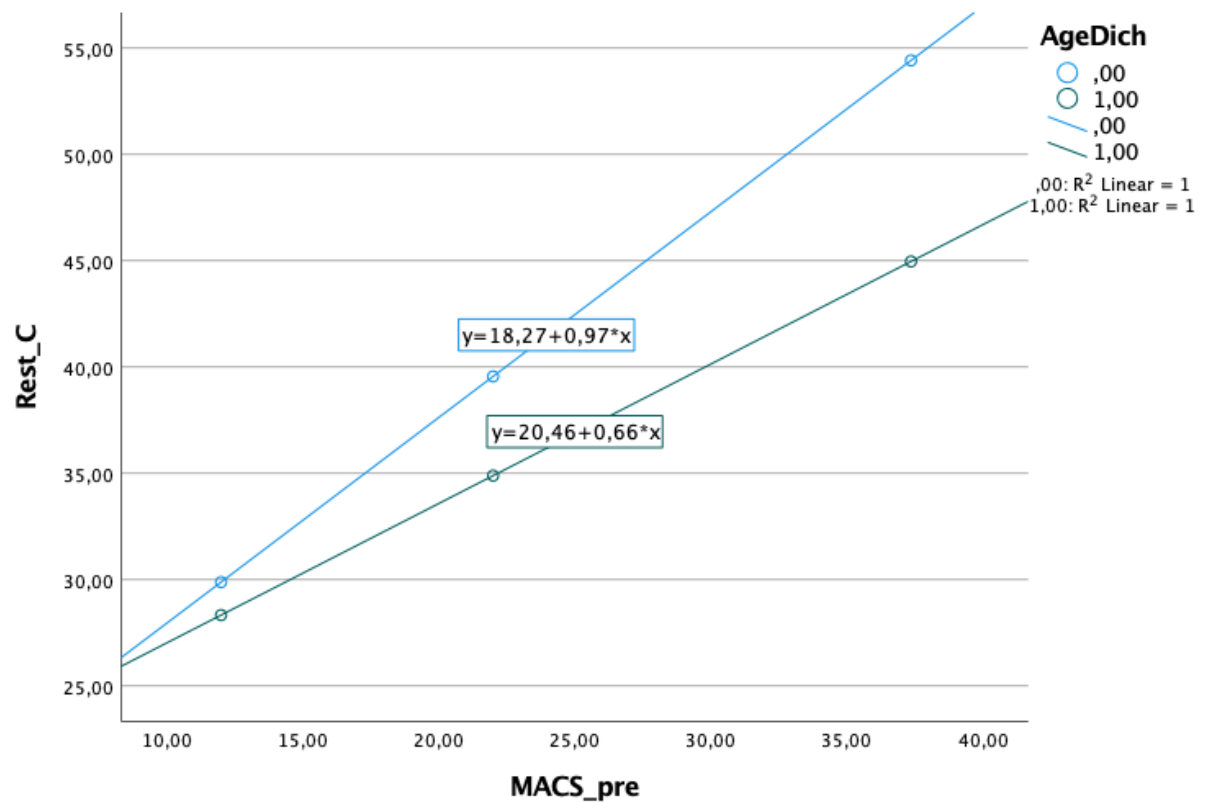**Appendices**

Appendix A

Visualisation of the Moderation Effect of Age for the Pub Environment
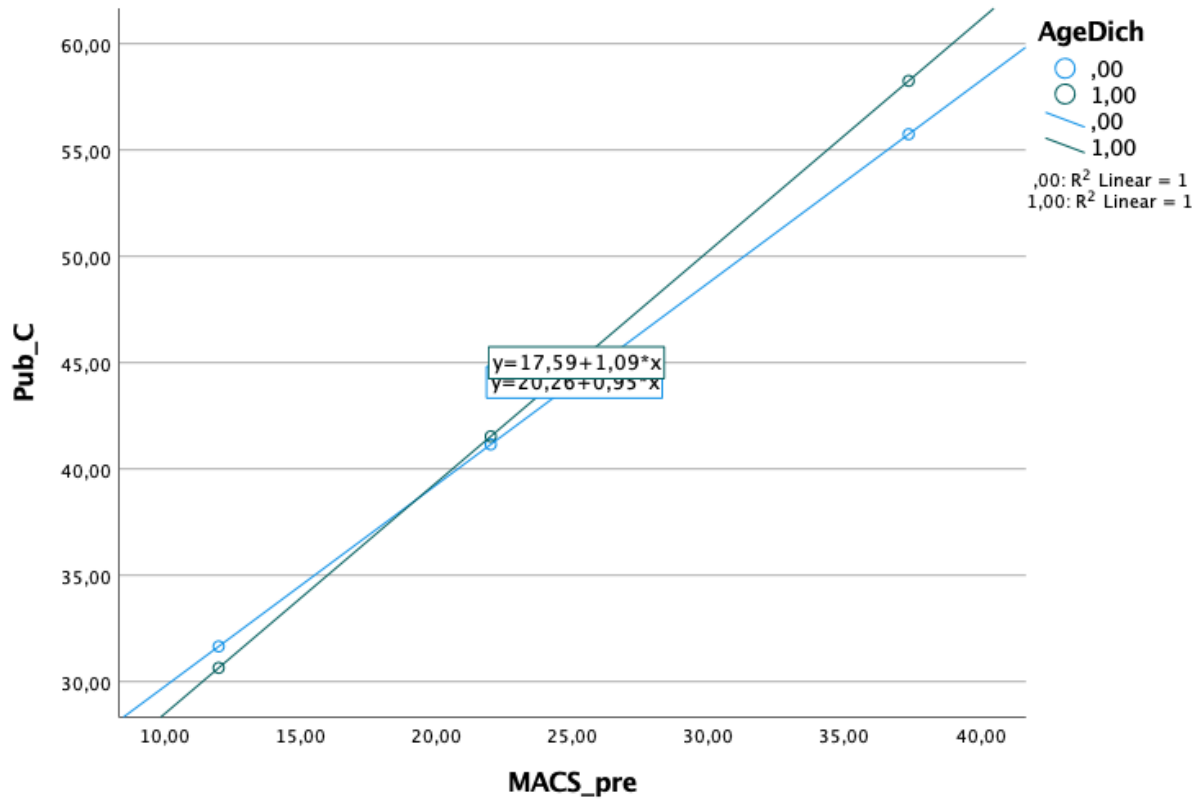
Note. Demonstration of the effect of general craving per young and old age condition on the cue-induced craving, with $1 = < 45$ of age and $0 => 45$ of age.

Appendix B

Visualisation of the Moderation Effect of Age for the Bar Environment

Note. Demonstration of the effect of general craving per young and old age condition on the cue-induced craving, with $1 = < 45$ of age and $0 = > 45$ of age.
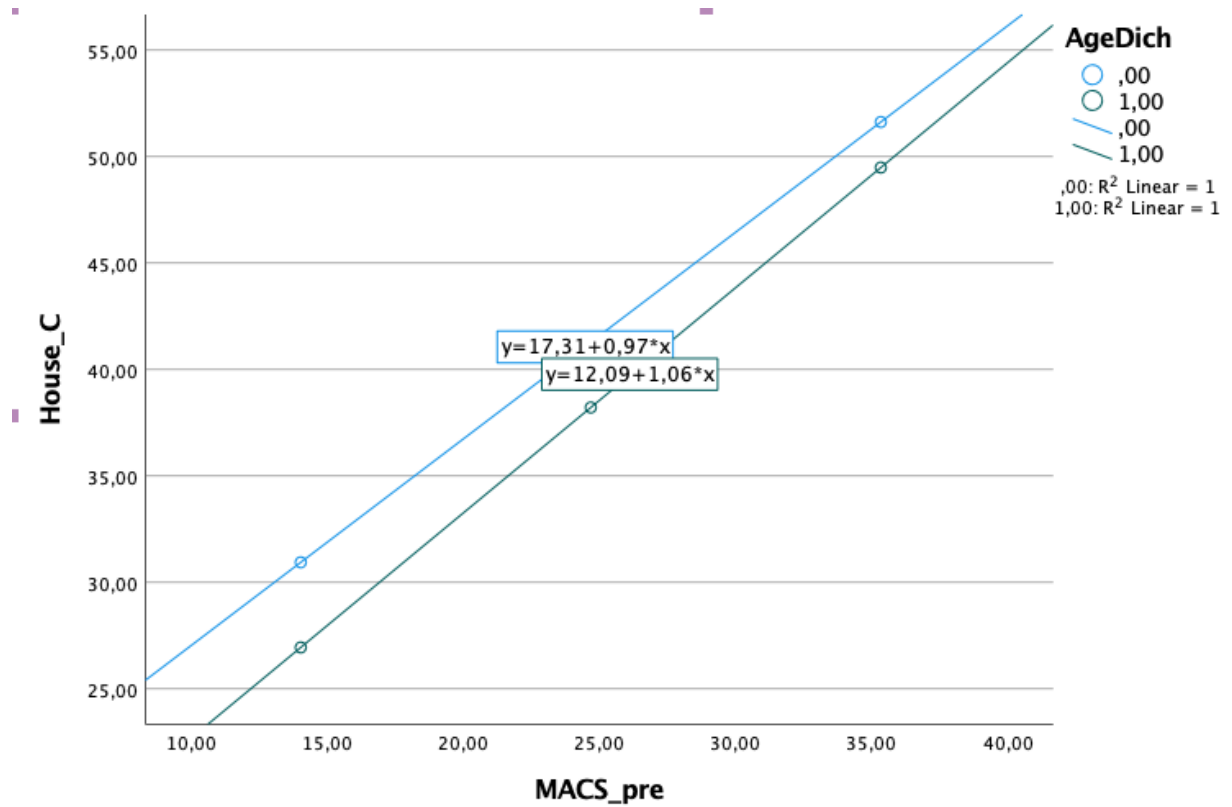
Appendix C

Visualisation of the Moderation of Age for the Restaurant Environment

Note. Demonstration of the effect of general craving per young and old age condition on the cue-induced craving, with $1 = < 45$ of age and $0 => 45$ of age.

Appendix D

Visualisation of the Moderation of Age for the Home Environment

Note. Demonstration of the effect of general craving per young and old age condition on the cue-induced craving, with $1 = < 45$ of age and $0 => 45$ of age.