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Location and Longing: The Nicotine Craving Experience in Virtual Reality

Brian L. Carter[a*], **Patrick Bordnick**[b], **Amy Traylor**[a], **Susan X. Day**[b], and **Megan Paris**[a,b]

a*M. D. Anderson Cancer Center, Houston, TX, 77230, USA*

b*University of Houston, Houston, TX, 77004, USA*

Abstract

Considerable research suggests that cigarette craving is complex, with psychological, emotional, cognitive, and behavioral aspects that are inadequately captured by typical craving assessments that focus on level of severity. That is, the experience of craving, for cigarette smokers, remains poorly understood. This study immersed smokers in different virtual reality (VR) scenarios (with and without cigarette cues present), collected detailed craving assessments, and analyzed the data using a multidimensional analytic approach. Non-treatment-seeking, nicotine dependent smokers (N = 22) experienced two different virtual reality scenarios, one with cigarette cues and one without, and rated 24 descriptors related to craving. Multidimensional scaling (MDS) models demonstrate that smokers' experience of craving is qualitatively, structurally different under VR smoking cue conditions versus neutral conditions. This finding sheds new light on the complexity of craving as well as implications for its measurement.

Keywords

Smoking; Craving; Multidimensional Scaling; Virtual Reality; Nicotine Dependence

1. Introduction

1.1. Craving

Numerous laboratory studies have demonstrated that individuals with substance use disorders have significant physiological and subjective reactions to presentations of drug-related stimuli, a phenomenon commonly known as cue reactivity (Carter and Tiffany, 1999; Niaura et al., 1988; Rohsenow et al., 1990). In laboratory investigations of these reactions, individuals with substance use disorders are exposed to both drug-related cues (e.g., cigarettes, bottles of alcohol, drug paraphernalia) and drug-neutral cues (e.g., pencils, glasses of water, a set of car keys) while differences in craving self-report, physiological responses, and, less frequently, drug-use behaviors are monitored. A recent meta-analysis of over 40 cue-reactivity studies with nicotine, alcohol, heroin, and cocaine dependent individuals strongly supports the finding that people with substance use disorders have significant cue-specific reactions to drug-related stimuli (Carter and Tiffany, 1999). In general, individuals with substance use disorders,

*Address all correspondence to, Brian Carter, Department of Behavioral Science, University of Texas M .D. Anderson Cancer Center, 1515 Holcombe Blvd.—Unit 1330, Houston TX 77230-1439, Office: 713-745-4294, Fax: 713-745-4286, e-mail: bcarter@mdanderson.org.

regardless of type of drug, report robust increases in craving and exhibit modest changes in autonomic responses, such as increases in heart rate and skin conductance and decreases in skin temperature, when exposed to drug-related versus neutral stimuli. When drug use measures are used in cue reactivity studies, the typical finding is a modest increase in drug-seeking or drug use behavior (e.g., Carter and Tiffany, 2001).

Over the past few decades considerable research has investigated cue reactivity in cigarette smokers. A variety of cue presentations has been employed including in vivo exposure (e.g., a lit cigarette), pictures (e.g., photos of cigarettes), and imagery scripts (e.g., smokers vividly imagine smoking scenarios). The findings from these studies are fairly consistent in terms of cue reactions. That is, regardless of cue presentation method, smokers report increases in craving with approximately one standard deviation in effect size. Autonomic responses (e.g., skin conductance increases), although smaller in magnitude (effect size d ~.2), are nevertheless often significant in these studies. Given the body of research in this area, laboratory investigations using cue exposure have clearly established cue reactivity methodology as a consistent and reliable way to induce craving in smokers.

Craving is fundamental to almost all models of addictive behavior, but the scientific community reports considerable ambiguity concerning the concept of craving, as noted by Tiffany, Carter, and Singleton (2000) in their paraphrase of a typical recommendation of national and international meetings on craving:

"Although we do not know what craving is and we can establish no consensus about the best way to measure it or manipulate it, we certainly believe that more research should be conducted on this possibly, but not necessarily, important construct" (p. S178).

Craving remains poorly understood; however, researchers have made clear distinctions between a generalized level of craving and craving that is evoked through exposure to cigarette cues (Tiffany, Cox, et al., 2000). In other terms, generalized craving is the relatively low level of craving that smokers report when exposed to neutral stimuli, compared to the spikes in craving that occur when a smoker is exposed to cigarette stimuli. Thus, the daily life of a smoker includes a background, generalized craving as well as spikes of cue-induced craving. Cue evoked craving is consistently found, yet few experimental manipulations have been discoveredthat modify it (e.g., Carter and Tiffany, 2001). It remains unknown whether the increases in craving found in the typical cue reactivity study denote an increase in the severity of the same construct, or whether the structure and nature of craving also change along with this increase.

Learning more about the very nature of craving, that is, what smokers mean, think they mean, feel, or are somehow expressing, when they are asked about their experience of craving, seems an important step in helping clear up this ambiguity. Various models of addiction emphasize different pathways through which craving is generated and manifested. For example, Baker, Morse, and Sherman's (1987) dual affect model posits that craving is mediated through the emotional systems in the brain. Tiffany's (1990) cognitive model of drug urges posits that craving is the result of interruptions in automatized behaviors. Although these models offer a logical structure under which craving should be increased or decreased, they are mostly silent on what the experience of craving is and what meaning it has for the person reporting it.

1.2. Rationale for Using Multidimensional Scaling

Multidimensional scaling (MDS) is a data gathering and analysis technique useful for exploring the nature of psychological constructs. MDS is particularly useful for understanding a construct when its structure is generally unknown or when there are differing perspectives on the nature of that construct (Ellroy et al., 1995). For example, Clark (1984) applied an MDS analysis to

pain, asserting that it "is a complex sensory and emotional experience which is extremely difficult to describe, and which is modified in poorly understood ways by arousal, expectations, suggestion and psychological factors" (pp. 349–350). Much the same description could be applied to the experience of craving. Currently, there is disagreement as to the meaning, definition, and interpretation of craving (e.g., Tiffany, Carter, et al., 2000), and craving is modified (e.g., by nicotine deprivation, cigarette availability) in poorly understood ways. MDS as a research tool for understanding complex psychological phenomena has demonstrated considerable versatility. It has been used to understand how people conceive of loneliness (Lunt, 1991), crowding (Sadalla et al., 1978), rape (Sugarman, 1994), virtue (Haslam et al., 2004), drinking (Rather et al., 1992), smoking marijuana (Linkovich-Kyle and Dunn, 2001), and job involvement (Ellroy et al., 1995), just to name a few.

Multidimensional scaling represents similarities and dissimilarities among stimuli as distances between points in graphic space: the main output is a plot showing points in two-, three-, or (rarely) higher-dimensional space. Like everyday graphing, the MDS plot has an X and a Y axis perpendicular to each other, and if there is a third dimension, a Z axis that shoots through the intersection of these indicating a plane above and below them. This display allows the researcher to see the data displayed in space, which often reveals features of the data that are not obvious in numerical displays, such as correlation tables (Borg & Groenen, 2005). The instruments used to collect MDS data frequently consist of judgments of similarity or co-occurrence among stimuli such as descriptors, products, or persons, without naming the quality the judgments should be based upon. In this way, the dimensions that result from data analysis come from within the participants as they employ their own mental rulers. These rulers are interpreted substantively from the MDS graphic plot by the researchers, using logical and theoretical bases. For example, when people are asked to judge similarities between pairs of familiar auto models, a plot is derived that displays autos from small to large on one axis and from cheap to expensive on another axis, even though the respondents were never told to judge by size and cost and may not be aware that they used these features in their judgments. It should be noted that MDS analysis does not indicate the participants' car preferences, but rather how they generally view the salient features of cars.

1.3. Virtual Reality

Researchers have explored the phenomenon of craving with studies that have typically employed simplistic cue presentations. Using isolated cues such as cigarette photos, lit cigarettes, or other smoking paraphernalia ignores the social, physical, and affective environments that smokers are typically immersed in, in the real world, when experiencing craving in response to smoking cues. Therefore, moving toward a method that presents specific cues (i.e. cigarettes) in more appropriate contexts (i.e. bar, home, office courtyard) can provide a more ecologically valid cue presentation, and we believe a more precise and accurate tool for researchers concerning a smoker's craving as it occurs in the real world.

Virtual reality (VR) cue exposure methods may provide a solution. Virtual reality incorporates a human-computer interaction that provides active participation with a three dimensional, multisensory virtual environment. Through perceptions of being both immersed and involved in the VR environment, the participant derives a sense of presence in the virtual world (Witmer & Singer, 1998). For example, a person experiencing a swinging bridge over a cliff in virtual reality will often sway, and the VR elicits reactions (e.g., mild anxiety, vertigo) similar to how they would feel on a bridge in the real world. For researchers, this sense of presence is essential in engaging the participant, allowing more realistic cue exposures to be implemented, and providing the participant exposure to complex cues in the context of realistic situations.

Bordnick and colleagues (2004) developed the Virtual Reality Nicotine Cue Reactivity Assessment System (VR-NCRAS) and tested it with thirteen nicotine dependent adult smokers.

They discovered that in response to VR smoking cues, there was a robust increase in smokers' craving self report compared to neutral VR environments. Bordnick and colleagues (2005) subsequently replicated these findings in another sample of smokers. These studies indicate that VR is a viable means of examining and assessing smokers' reactions to complex smoking cues observed in a contextually appropriate environment. Thus, VR is an ideal environment to test potential changes in the nature of craving, using MDS methodology, when self report of craving is compared between neutral and cigarette related scenarios.

2. Methods

2.1. Participants

Participants were predominantly college student smokers (N = 22) who were not seeking treatment. Inclusion criteria included providing informed written consent to participate, meeting the DSM-IV criteria for nicotine dependence, being between the ages of 19 and 24, being in good physical health, and being able to wear a VR helmet for approximately 40 minutes. The mean age of participants was 20.8 (SD = 1.4), and they reported smoking 20.8 cigarettes per day (SD = 5.2).

Exclusion criteria included having a current or past diagnosis of DSM-IV recognized severe mental illness (mood disorder, anxiety disorder, schizophrenia, obsessive compulsive disorder, PTSD, or eating disorder) or current DSM-IV diagnosis of dependence for a substance other than nicotine (within the past 30 days); taking medication or drugs that may have an effect on nicotine craving or consumption, mood, or ability to participate in the past 30 days; being pregnant; engaging currently in smoking cessation treatment; fearing closed spaces; having visual problems that would affect viewing VR environments; or having a history of seizure, seizure disorder, or other serious health problems. Participants were not restricted in their use of caffeine.

2.2. MDS Instrument Development

Ideally, the list of MDS descriptors in the measure used should be as long as practical and include as wide a content range as possible, in order to allow for the uncovering of a number of dimensions. Davison (1992) suggests five or more stimuli (descriptors) for each dimension expected to emerge in a multidimensional solution. Twenty varied descriptors are plentiful enough to support two or three dimensions of the craving experience.

The compilation of the MDS descriptors, following these guidelines, was done with a combination of three strategies. The rational method involved choosing descriptors suggested by theory. For example, Baker, Morse, and Sherman's (1987) dual-affect model proposes two craving systems, one based on positive and the other on negative affect. This theory suggests that emotional descriptors should be included in the MDS instrument. The lexical method involves referring to synonymies and thesauruses for terms close in meaning. For example, synonyms for the word "craving" include "urge," "desire," and "lust for." The lexical method posits that salient aspects of the experience are encoded in natural language. The free listing method is an open-ended task that has smokers generate a list of adjectives and phrases related to their own craving experience. This method has been followed in previous research by Shadel, Niaura, Brown, Hutchison, and Abrams (2001), who performed content analysis of 42 smokers' descriptions of their cravings. Their list of descriptors was used in developing the instrument for this study. Once a pool of descriptors was compiled from these three sources, we culled out repetitious descriptors and chose 20 descriptors for the MDS instrument, and we added four items from the Questionnaire on Smoking Urges (QSU; Tiffany and Drobes, 1991).

The completed MDS instrument has descriptors designed to assess the underlying structure of craving in four content areas: physiological, affective, cognitive, and behavioral. The MDS instrument is represented in Table 1. Each question was presented with the heading "AT THIS MOMENT." The rating scale was an 11 point scale from 0 = Not at all to 10 = Extremely. In addition, a four item subscale of the Questionnaire on Smoking Urges (Tiffany and Drobes, 1991) was included in the MDS instrument as a confirmatory measure (i.e., to verify that craving was induced) and to let us observe where they fit into the spatial display of the structure of the craving experience. The four QSU items used were the same as those used by Tiffany and colleagues (Carter and Tiffany, 2001;Cern, Bailey, and Tiffany, 2002;Bailey, Cern, and Tiffany, 2002) and have been shown to have a high degree of reliability to detect craving changes between neutral and cigarette stimuli.

A priori power estimates to determine sample size are not made in multidimensional scaling, because in some explorations a very low *N* is required for an accurate representation of the stimulus space (Stalans, 1995). Davison's (1992) formula for number of raters is $N = 40K^*/(I - 1)$, when I is the number of stimuli (in this case 24) and K* is the anticipated number of dimensions (in this case a maximum of three). In the proposed study $N = 120/23 = 5.2$, meaning that, with a sample size of 22, we had more than an adequate number of raters to get an accurate representation of the stimulus space.

2.3. Virtual Reality Environments

The VR environments analyzed in this study consisted of two rooms, a nature scene (with neutral cues) and a party scene (with cigarette cues). In the neutral room, participants watched narrated nature scenes, devoid of smoking cues, presented with floral scent (neutral scent to control for scent in the smoking cue scenario). In the party environment, participants were exposed to inanimate cues such as cigarettes and lighters while interacting with other smokers in a party setting that included music and olfactory cues such as cigarette smoke, food, and alcohol scents. Both rooms contained visual, auditory, and olfactory stimuli appropriate to the given environmental context. Participants were guided through each room on a computerized path and all exposure times were standardized and controlled by the computer software, with participants spending 3 minutes in each room.

2.4. Procedures

After obtaining informed consent, the researcher administered questionnaires and rating scales to each participant, including a smoking history, the Questionnaire of Smoking Urges, and Cigarette Craving Visual Analog Scale (CCVAS).

After completion of these measures, participants completed a 15-minute VR acclimation session, with an environment unrelated to the study, to provide familiarity with the procedural aspects of the study. Once participants felt comfortable wearing the helmet and using the controller and any questions about the procedures were answered, they were asked to smoke one cigarette in order to standardize the time since last exposure to nicotine. They then spent 3 minutes in the neutral environment, followed by 3 minutes in the cigarette-cue virtual reality environments. After each environment, participants were asked to use a handheld game pad to complete the MDS questionnaire projected into the VR rooms[1] The type of environment was not counterbalanced in order to prevent carryover effects. Previous VR studies produced large effect sizes, and participants often do not return to a baseline level of craving when entering a neutral environment after a smoking cue environment. This suggests the likelihood of strong

[1]Four VR environments were actually used in the experiment, with one cigarette-cue and one neutral-cue environment being used in the current MDS analysis and two cigarette-cue and two neutral-cue environments being used in another analysis (available in Traylor, 2007).

carryover effects which would obscure the main craving effect if counterbalancing was employed.

2.5. Data Analyses and Statistical Approach

The current MDS module in the SPSS statistical package, ALSCAL (Takane et al., 1977), was employed. MDS depicts in comprehensible graphic form the perceptions of an experience like craving. This scaling process uses similarity matrices (in this case, correlation matrices) to derive coordinates that show similarity and dissimilarity among MDS craving items in relation to each other as closeness and distance in space. The correlations between all pairs of items are transformed into Euclidean distances, with higher correlations meaning closer distances to reflect the mental geography used by participants. If **X** is the m-dimensional configuration (the MDS space), the formula corresponding to the length (d) of a straight line segment connecting points i and j in m-dimensional space is

$$d_{ij}(\mathrm{X}) = \left[\sum_{a=1}^{m}(x_{ia} - x_{ja})^2\right]^{1/2}$$

As this formula indicates, d_{ij} (**X**) is the square root of intradimensional differences, $x_{ia} - x_{ja}$: that is, the Pythagorean theorem for the length of the hypotenuse of a right triangle.

Finally, through an iterative process, the MDS program arranges the stimuli as points in m-dimensional space in such a way that the distances between each item and all the others are as close as possible to the distances derived from the correlation matrix.

The stimuli are the twenty-four terms that describe craving, developed for the study. Each participant rated these terms by how strongly each one described their immediate experience under each of two VR conditions, and the correlation lower-half matrices from these ratings served as the similarity matrices for the analysis. Similarity is defined as patterns of co-occuring endorsement among descriptors.

The derived coordinates are used to plot visual representations of the stimuli in relation to each other. The analysis provides sets of coordinates in as many dimensions as the results justify, and each n-dimensional set of coordinates is called a solution. Each dimensional solution is assessed for how well it accommodates the relations between variables, and this assessment is represented by a goodness-of-fit statistic. This statistic is a stress value, with less stress meaning better representation of the stimuli. (Thus, stress is actually a badness-of-fit measure.) Stress values at various dimensionalities indicate where the analysis has arrived at an acceptable representation of the relations among stimuli.

The scaling process seeks an analysis of data from two sources—here, the party and neutral conditions. If individuals' reponses are highly different from each others' in one condition, the scaling process will not come to a satisfactory solution, which will be reflected in a high level of stress. The stress value indicates how much the process has to distort the data to come up with an overall analysis. In other words, high stress values mean that the overall analysis is an inadequate representation of the original data because data fit only when strained to do so. Stress values near .10 are acceptable for representative dimensionality and rarely are below .05 (Davison, 1992).

Multidimensional scaling produces separate solutions for each VR condition. Therefore, if the dimensions hold different meanings or salience for each condition, the maps of the stimuli will appear different.

3. Results

3.1. Craving in Two VR Settings

One basic question is whether participants experienced higher levels of craving in the party (cigarette-cue) VR room than in the nature (neutral cue) VR room, as one would expect. They did ($t = -3.29$, $p < .01$). The eta squared (an estimate of effect size) for this comparison was .34, based on the mean of their responses to the four items of the QSU. Cronbach's alphas for the QSU were .93 in the neutral VR condition and .97 in the cigarette cue VR condition.

3.2. Euclidean Distance Models of Craving Under Two VR Settings

Figure 1 shows the two-dimensional solution for the VR neutral scene MDS craving questionnaire, and Figure 2 shows the two-dimensional solution for the VR party scene MDS questionnaire. Both configurations delete the behavioral items from the analysis: smoking soon after waking up in the morning, grabbing a quick smoke before a movie or airplane flight, smoking with other smokers, smoking during leisure times, and having special times when I enjoy smoking most. These items, under MDS analysis, were so closely grouped and separated so clearly in both plots from all other items that they created a blatant behavioral-nonbehavioral first dimension which we did not consider informative for our research questions, which sought more subtle experiential dimensions. An analogy may help: if we had included five items about alcohol craving, the first dimension would separate all the alcohol items from all the smoking items. We consider that our behavioral items, which were longer and more concrete than the others, were perceived in a separate category from our other items, though they were originally derived from smokers' free form descriptions of craving.

In Figure 1 and Figure 2, the first letter of the descriptor denotes the domain (Physiological, Affective, Cognitive, or QSU). The rest of the label abbreviates the item (e.g., "thinktaste" means "I am thinking that a cigarette would taste good right now." See Table 1 for the list of items and abbreviations.

For each of these visual plots, the stress values and proportion of variance explained by the two-dimensional solutions were acceptable (Neutral scene, Stress = .13 and RSQ = .93; Party scene, Stress = .10 and RSQ = .95). Notice that in neither plot are similar conceptual domains of items (P, A. C, or Q) strictly clustered along one or the other dimension.

4. Discussion

4.1. Eliciting Craving in Virtual Reality

As previous research has asserted, cigarette cues produced significantly stronger craving in smokers than neutral cues. This study showed that the expected effect occurs in virtual reality cue environments, as it does in other experimental methods. Moreover, the craving effect size is similarly large as that found in Carter and Tiffany's (1999) meta-analysis (eta squared = .34). According to Cohen (1988), eta squared values of .01, .06, and .14, respectively, represent small, medium, and large effect sizes. Carter and Tiffany (1999) reported that smoking cues in the typical cue reactivity study also produce large craving effect sizes. This finding is noteworthy because the participants were completely nondeprived, having smoked a cigarette just before undergoing cue exposure. This nondeprived situation should produce the lowest amount of cue reactivity.

4.2. Comparison of the Craving Experience in Neutral and Cigarette Cue Conditions

Though both Figure 1 and Figure 2 hold psychometrically sound properties (high RSQs and low stress values), the dimensions (the interpretation of which is the purview of informed researchers) appear to hold different meanings for participants in the cigarette-cue condition

and in the neutral condition. In Figure 1, Dimension 1, on the x axis, is anchored at one extreme by “I am energized” and at the other by “I am out of control,” both high arousal items, with all the other descriptors clustered toward one end of the scale in an array difficult to interpret meaningfully. The second dimension, on the y axis, appears to suggest a continuum ranging from of physical and emotional arousal to physical and cognitive passivity. The QSU items, usually the benchmarks of craving measurement, are clustered near the 0,0 point, indicating that they are not well reflected by these two dimensions at all. A point close to 0 on any dimension means that participants’ responses did not load on that dimension.

In Figure 2, which arrays responses under the cigarette-cue condition, the dimensions are much clearer. Dimension 1, on the x axis, now shows descriptors scattered loosely along the continuum of positive to negative. In fact, the left side of Dimension 1 includes all the positive reasons to smoke (approach motivations), and the right side of Dimension 1 includes all the negative effects that would be relieved by smoking (avoidance motivations). The second dimension, on the y axis, is anchored by energy and excitement at one end and tiredness at the other, in an arousal/nonarousal arrangement where most of the items lie near the middle. All of the QSU items are arranged on the left (approach motivation) end of Dimension 1, suggesting that they do not tap into avoidance motivations associated with craving in the cigarette-cue condition. The QSU items, like most others in this configuration, lie close to 0 on Dimension 2, indicating that arousal is not a highly salient feature of these descriptors. This suggests that the QSU items define craving by the approach motivations only, not by avoidance motivations or by arousal level. So, though these features of craving came out in the MDS plots, they would not be measured by the QSU alone

Therefore, this study suggests that craving not only differs quantitatively under neutral and cigarette-cue conditions; it also is qualitatively, structurally different under non-cue and cue conditions. The VR party context elicits a first dimension clearly arrayed according to types of reasons to smoke, unlike the VR neutral scene. Furthermore, the short-form QSU questionnaire presents an impoverished picture of the complex experience of craving, as would any simple craving assessment such as a single item visual analog scale.

A significant limitation of the present study should be noted. This study was conducted with young adult smokers, and it remains unclear whether the same pattern of MDS plots would emerge in other smokers (e.g., adult, long-term smokers, smokers seeking treatment, poly substance users, etc.) or in response to different environments (e.g., smoke break at work, a crowded airport smoking lounge, etc). Our laboratory is currently conducting the same MDS protocol on varied groups and environmental contexts, as well as determining whether various cue presentations (e.g., in vivo, cigarette pictures) produce similar MDS plots. Although physiological correlates of craving have been found in numerous studies (Carter & Tiffany, 1999) multidimensional scaling differs from traditional scaling in that it does not require known measurable dimensions (such as heart rate and skin conductance) to be defined in advance. Multidimensional scaling was created for exploration of complex constructs such as people's perceptual, cognitive, and psychological representations of experience.

4.3. Implications for Craving Research

A tacit assumption in almost all craving research is that craving is a unitary phenomenon. That is, the experience of craving is the same for all people and varies only in intensity. Considerable empirical evidence, from a number of fields related to addiction, suggests a high degree of variability in how addictive behaviors are expressed. This evidence strongly questions the validity of this unitary assumption. Moreover, an examination of the craving research from the past 40 years reveals an incremental and generally slow progress toward a better understanding of what craving is and how it fits into the addictive process. A possible cause for this lack of

progress could lie in the fundamental lack of understanding of the psychological structure of craving self-report.

Several advantages in the use of VR should be noted. First, VR can produce complex realistic environments in a confidential, safe, controlled laboratory setting. Because of its ability to provide the participant with an immersive experience, virtual reality may be an effective alternative to visualization or imaginal scripting methods of exposure. The stimuli are controlled by the program and, thus the researcher can discuss specific cues or responses with the participant. In addition, VR is capable of offering standardized exposure to stimuli with zero variance between presentations of cues, experimental trials, and research settings, allowing for precise replication of studies.

Second, studies from this laboratory have shown VR cue reactivity methods to produce strong cue responses as evidenced by large effect sizes (P.S. Bordnick et al. and A.C. Traylor et al., personal communication). Larger effect sizes require fewer participants for testing and provide an increased ability to detect smaller differences as a result of other experimental manipulations (e.g. craving context, anti-craving medication effects).

Third, VR is uniquely suited to take advantage of the "proteus effect" (Yee & Bailenson, 2007). This effect is achieved by creating an avatar (a computer generated likeness) of the participant, but subtly altering the features of the avatar to suit an experimental question. For example, Yee and Bailenson (2007) created participant avatars that were either taller or shorter than the other avatars in the VR environment. Regardless of the actual height of the participant, people assigned to taller avatars behaved more confidently in a subsequent negotiation task. This is a powerful effect. When a participant enters a virtual world with an avatar that is subtly altered, the participant's subsequent real world behavior is significantly altered. This effect has important implications for smoking cessation treatment. For example, altering a smoker's avatar to be confident and relaxed in the face of temptation could possibly produce the same behavior in the real world.

In summary, the research reported here offers a more nuanced definition of what it is smokers are reporting when they report craving. In addition, the study determined that there are qualitative differences in smokers' craving experience under various VR cue conditions. These findings, which explore craving at the basic level of meaning, have broad implications for craving research methodology and addiction theory.

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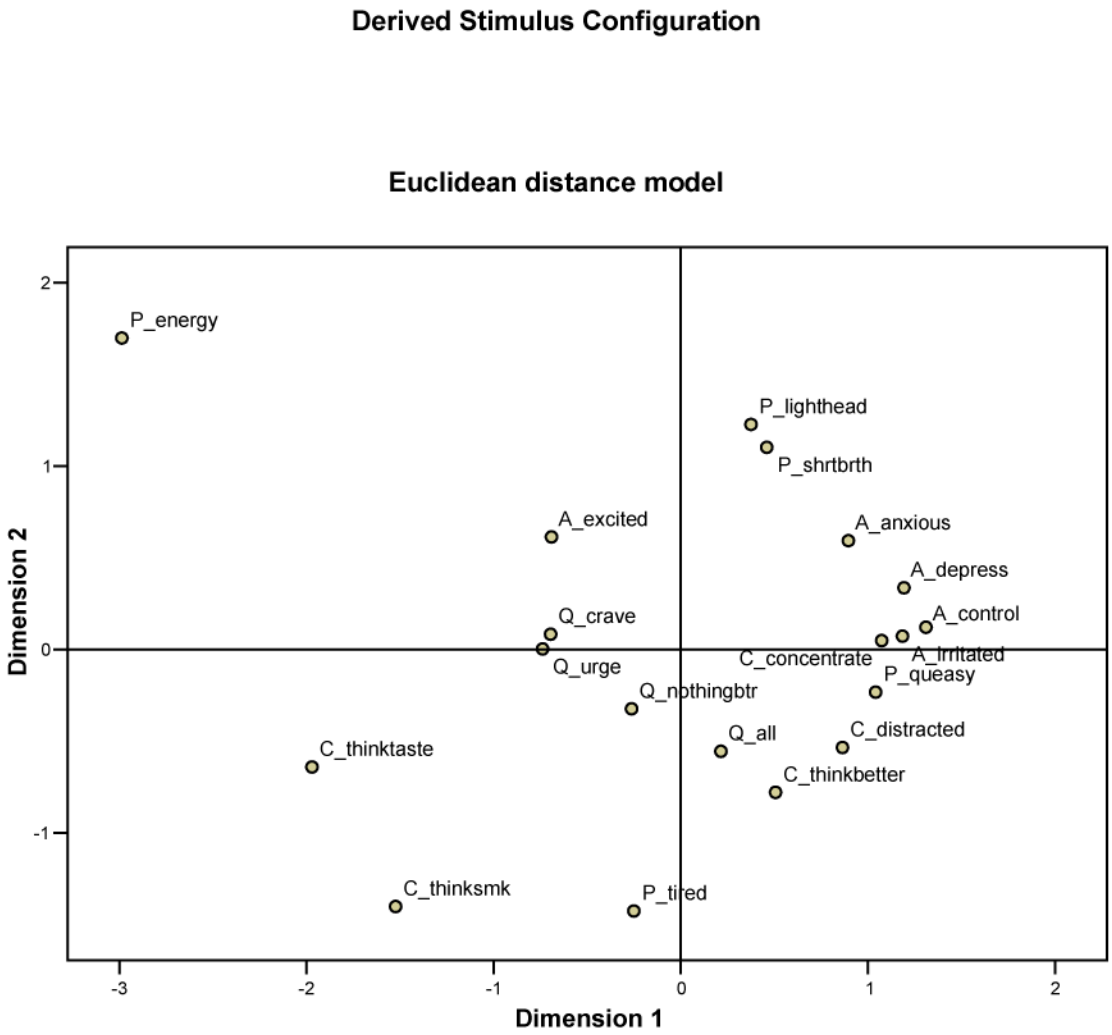

Figure 1.
Two-dimensional solution for the VR neutral scene MDS craving questionnaire.

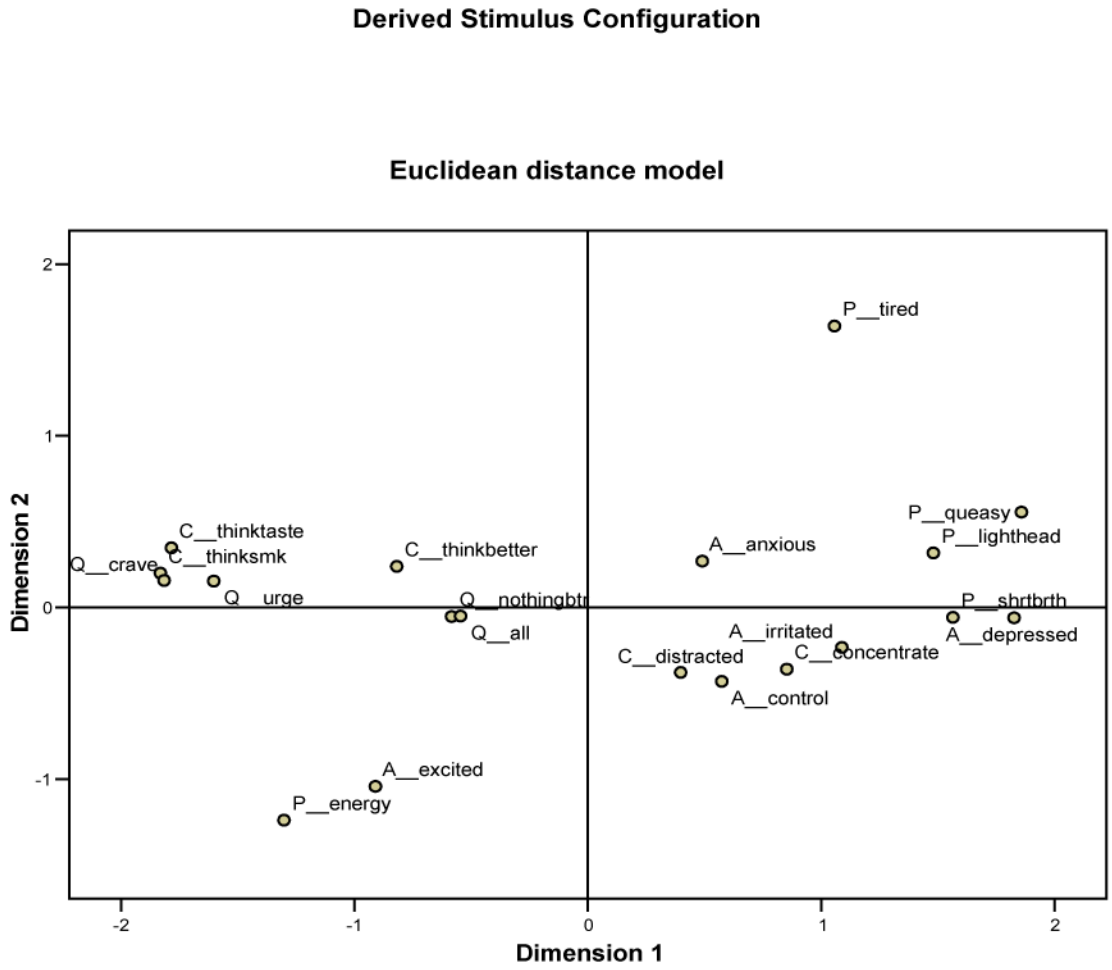

Figure 2.
Two-dimensional solution for the VR party scene MDS craving questionnaire.

Table 1

MDS Descriptors

Descriptor	Abbreviation	Domain
I am out of control	Control	Affect
I am depressed	Depressed	Affect
I am irritated	Irritated	Affect
I am anxious	Anxious	Affect
I am excited	Excited	Affect
I see myself smoking soon after waking up in the morning	Waking	Behavioral
I see myself grabbing a quick smoke before a movie or airplane flight	Movie	Behavioral
I see myself smoking with other smokers	Others	Behavioral
I see myself smoking during leisure times like playing cards, drinking, or outdoor activities	Leisure	Behavioral
I see myself as having special times (like after meals) when I enjoy smoking most.	Specialtimes	Behavioral
I am distracted	Distracted	Cognitive
I am having trouble concentrating	Concentrate	Cognitive
I am thinking about smoking	Thinksmk	Cognitive
I am thinking that things would be better if I could smoke right now	Thinkbetter	Cognitive
I am thinking that a cigarette would taste good right now	Thinktaste	Cognitive
I am light headed	Lighthead	Physiological
I am short of breath	Shrtbrth	Physiological
I am tired	Tired	Physiological
I am queasy	Queasy	Physiological
I am energized	Energy	Physiological
I crave a cigarette right now	Craver	QSU item
Nothing would be better than smoking a cigarette right now	Nothingbtr	QSU item
All I want is a cigarette right now	All	QSU item
I have an urge for a cigarette	Urge	QSU item