

# ATHOS: a dATabase of 48 3D Human virtual characters with non-emOtional facial expreSsion for virtual reality

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1 2 3	ATHOS: a dATabase of 48 3D Human virtual characters with non- emOtional facial expreSsion for virtual reality
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11	Running head: Set of neutral virtual characters
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## 18 Abstract

19 An increasing number of studies in the Human and Social Sciences and Information and Communication Technologies and Sciences are conducted in virtual reality. Many of them use 20 21 3D human-like computer-generated characters in order to study social interactions in healthy 22 participants, or the effect mental illness or neurological disorder on social cognition. However, 23 free access to virtual characters is still not straightforward with often a lack of psychological 24 evaluation of available characters. We present here the ATHOS database composed of 48 25 Caucasian male and female virtual characters with non-emotional facial expression available in 26 the FBX file format. For each of them, we provide an evaluation in terms of valence, reliability, 27 sympathy and sociability. Concerning these evaluations, inter-rater reliability analysis revealed 28 a good degree of agreement among raters (between 0.85 and 0.98) and a cluster analysis 29 highlighted a division of the virtual characters into three groups (low, medium and high 30 evaluation scores). The ATHOS database of virtual characters, available in open access, can be 31 used for many different purposes including the development of social immersive virtual 32 environments, cognitive assessments or even rehabilitation programs in the health domain.

33

Keywords: Human virtual character; non-emotional facial expression; 3D environment; virtual
reality; inter-rater reliability; cluster analysis, FBX file format

36

## 38 Introduction

39 Immersive Virtual Reality (IVR) is being increasingly used in everyday life, whether 40 for entertainments, distance learning, advertising, consulting or business activities [1]. The 41 expansion of its use is also visible in the field of research with an increasing number of IVR-42 based studies in the Human and Social Sciences and Information and Communication 43 Technologies and Sciences. Virtual environments offer the possibility of getting closer to 44 ecologic and realistic situations while allowing a strong experimental control [2,3]. Those 45 conditions, often difficult to combine, are essential to improve acceptance of digital devices 46 and replicability of experimental research, which makes virtual reality a precious tool in the 47 domain of perceptual, behavioral, cognitive, affective and social studies.

48 In order to study social interactions and their effects on cognitive processes, many 49 researches have used naturalistic stimuli such as virtual characters or avatars [2]. Their presence 50 in a virtual environment is sufficient to develop a feeling of social presence [2], and they are 51 usually used to investigate social cognition and social skills. Virtual characters are for instance 52 of great interest in the study the effects of social constraint on the adjustment of interpersonal 53 distances [4] and the data are consistent with those obtained in real social situations [5]. They 54 are also increasingly used in the context of pathological populations for diagnosis and for 55 developing new technological-based therapeutic tools. For instance, virtual characters were 56 used for training social skills in patients with autistic spectrum disorder [6] or in exposure 57 therapy associated with social anxiety treatments [7].

58 Despite human-like stimuli are increasingly used in various scientific and applied 59 domains, there is still a limited access to computer-generated virtual characters, in particular 60 those that offer realistic design and are freely available online. We present here an open access 61 database of 48 male and female Caucasian virtual characters with non-emotional facial 62 expression, which was developed at the University of Lille, on the basis of a survey performed online by a number of spontaneous volunteers. The ATHOS database provides for each of the
virtual characters an evaluation in terms of valence, reliability, sympathy and sociability. The
process for designing and animating the virtual characters is detailed below. The ATHOS
database also provides the raw data and a statistical analysis of the reliability of the inter-raters'
evaluation as well as a cluster analysis of the stimuli (S1).

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## 69 Method

### 70 **Participants**

The evaluation of the virtual characters was performed online by self-volunteer participants using the LimeSurvey website. The link to the survey was shared on social networks by students in Psychology from the University of Lille (France). From the set of 189 of self-declared participants, only 46 of them completed a minimum of 75% of the survey items and were retained for the data analysis. Among the participants, twenty-seven were females, heighten were males and fourteen did not report their gender. Mean age was 22.11 years (18-36, S.D.= 3.44) and mean study level was 1.80 year after the bachelor's degree (S.D.= 1.56).

### 79 Stimuli

Forty-eight Caucasian virtual characters (24 females) with a non-emotional facial expression were created from the Beta version of Adobe Fuse CC, using either the Female or Male "Fit A" model. The proportion of the different body parts was at the medium level according to the scale of the software. All virtual characters had a casual-to-classic dress code including no make-up or jewelry. In order to limit any clipping effect resulting from animation, all virtual characters wore pants. Once created, the virtual characters were exported in OBJ file

86 format and their textures were also saved in PNG file format. The OBJ version of the virtual 87 characters was uploaded to www.mixamo.com in order to be manually rigged. This procedure enabled to associate different animations with each virtual character. Finally, they were 88 89 exported in FBX file format. The FBX version of each virtual character as well as their textures 90 in full-body pictures available PNG and а are at the following address 91 https://osf.io/sp938/?view only=7a5c397f51864d88a7f71af2c18bf478. The file also contains 92 the data related to the individual evaluation.

93

94

## **Evaluation procedure**

95 The evaluation of the virtual characters was performed online using the LimeSurvey 96 website (version 2.63.1) hosted by the University of Lille' servers. The first page of the website 97 provided the instructions concerning the evaluation task. On the second page, participants 98 provided personal information concerning their gender, age and level of education. Then, on 99 the following pages, successive pictures of one virtual character (randomly selected) was 100 displayed above four successive evaluation scales. For each visual character, the evaluation was 101 made by positioning a cursor on a continuous line according to four criteria: valence, reliability, 102 sympathy and sociability. Each criterion was evaluated according to two opposite levels: 103 negative/positive for valence, not reliable/reliable for reliability, unsympathetic/sympathetic for 104 sympathy and not sociable/sociable for sociability. To avoid random evaluation for some of the 105 criteria, participants were instructed to respond to each criterion only if they can provide an 106 evaluation. The completion of the survey took about 25 minutes.

### 107 **Data analysis**

#### 108 Inter-rater reliability

109 The degree of agreement among participants (raters) for each evaluation was carried out 110 using Intraclass Correlation Coefficients (ICCs) with the iccNA function (irrNA package, 111 version 0.1.4, Brueckl & Heuer, 2018) of R and R Studio software (version 3.5.1 and 1.1.463 112 respectively). This function adopts the ICC conventions of Shrout & Fleiss (1979) and allows 113 ICCs computation with missing data by approximating the missing raters' individual effects. 114 ICC estimates and their 95% confident intervals calculation were based on a mean-rating (k =115 46 raters), the absolute-agreement, and a 2-way random effects models. The ICC estimate was 116 significant if p-values <.05. Conventionally, estimates less than 0.5, between 0.51 and 0.75, 117 between 0.76 and 0.9, and greater than 0.9 respectively indicated poor, moderate, good and 118 excellent reliability.

119

#### 120 **Cluster analysis**

121 A cluster analysis was performed using the k-means algorithm [8] from the stats package 122 of R (kmeans function) as a function of the 4 evaluation criteria. The Elbow method was initially 123 used to determine the appropriate number of clusters according to the dataset. The k-means 124 algorithm computed a partition of the virtual characters into different clusters such that the sum 125 of the Euclidian distances between the virtual characters of the clusters and their center was 126 minimized. The algorithm performed 20 iterations in order to enhance the odds of selecting the 127 best clustering model. Then, the Silhouette method was applied for validating the consistency 128 of the assignment of each virtual character to each cluster. Virtual characters with a Silhouette 129 width close to 1 were very well clustered, whereas those close to -1 were likely to be assigned 130 to a wrong cluster. Figs 2 and 3 representing the k-means analysis and the Silhouette method 131 were computed using respectively fviz\_cluster and fviz\_silhouette functions (factoextra132 package, version 1.0.5).

133

## 134 **Results and Discussion**

Considering the different criteria, the evaluation score was on average 5.03 (SD = 2.09)for valence, 4.86 (SD = 2.16) for reliability, 5.15 (SD = 2.23) for sympathy and 5.15 (SD = 2.24) for sociability. S1 Table summarizes the mean, standard deviation and the number of missing ratings for the 4 evaluation criteria and for each virtual character as well as the gender of each virtual character. The number of responses for the criteria considered together was thus 95.21% (4.79 % of missing data).

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## 142 Inter-rater reliability

143 Intraclass Correlation Coefficients estimates of each evaluation criterion are reported in 144 Table 1. The corrected mean ratings for each criterion are available in S1 Table (ICC Corrected 145 Mean). The inter-rater reliability analysis for each evaluation criterion revealed a good degree 146 of agreement among the raters (k = 46 participants) with a correlation estimate varying between 147 0.85 and 0.89. Thus, participants were consistent in their judgement throughout the evaluation 148 of the different virtual characters and they were also consistent with each other.

149

Criterion	Estimate	p value	95 % CI
Valence	0.88	< 0.001	[0.82 - 0.92]
Reliability	0.85	< 0.001	[0.78 - 0.9]
Sympathy	0.89	< 0.001	[0.85 - 0.93]
Sociability	0.87	< 0.001	[0.81 - 0.92]

#### 150 **Table 1: Inter-rater analysis**

151 ICC estimate of the Absolute-Agreement, 95% Confidence Interval and associated p-value per152 evaluation criterion.

### 153 Cluster Analysis

As illustrated in Fig 1, an elbow appeared at k = 3 suggesting that the dataset can be organized in three clusters, corresponding to low, medium and high evaluation scores.

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157

158 Fig 1. Elbow Plot. Total of within cluster sum of squares as a function of number of clusters159 computed from Elbow method.

160

The cluster assignment following the k-means clustering for each virtual character is reported in Table S1 and illustrated in Fig 2. The center of each cluster for each evaluation criterion and the within cluster sum of squares are reported on Table 2. Cluster 1 gathers 13 virtual characters (8 males, 5 females) with higher evaluation scores for every criterion, Cluster 2 gathers 23 virtual characters (12 males, 11 females) with medium evaluation scores for every criterion and Cluster 3 gathers 12 virtual characters (4 males, 8 females) with lower evaluation scores for every criterion. Thus, even though every virtual character was non-emotional, their facial characteristics varied, as a consequence so did their evaluation, resulting in the emergence
of three groups of virtual characters. Indeed, the evaluation of an emotionally neutral face can
vary depending on the potential structural resemblance of the face with an emotional expression
[9], as it has also been shown in the evaluation of dominance and submissiveness dimensions
[10].

173

# 174 Table 2: Cluster analysis175

Cluster	Size	Valence	Reliability	Sympathy	Sociability	Sum of Squares
Cluster 1	13	6.1	5.84	6.28	6.23	11.02
Cluster 2	23	4.9	4.75	5.03	5.05	10.91
Cluster 3	12	4.05	3.93	4.03	4.11	6.61

176 Clusters' size and center for each evaluation criterion, and within cluster sum of squares

177



179 Fig 2. Cluster Plot. Two-dimensional cluster plot of the virtual characters and their associated 180 clusters (high scores: squares, medium scores: circles, low scores: triangles). The (x, y) axes 181 represent the first two components, computed directly from the plot function, are derived from

the evaluations of the virtual characters and explain 97.4% of their variability. The larger square, circle and triangle represent the center of each cluster. The distance between each virtual character and its cluster's center represents the distance between them scaled on the two components representation.

186

187 The goodness of the assignment of each virtual character to its cluster is illustrated by 188 the Silhouette analysis. Visual analysis of Fig 3 highlighted the reliability of the assignment of 189 each virtual character in its respective cluster, although some of them (width close to 0) could 190 have been assigned to a neighbor cluster. For example, virtual character F01 was assigned to 191 cluster 2 with a score close to 0, indicating that it could have also been assigned to cluster 1, 192 the closer cluster neighbor. These variations can be explained by the non-emotional expression 193 of the virtual characters. Indeed, although the cluster analysis suggested 3 clusters, the center 194 of each cluster varied only little according to the others, due to the small variations of the 195 evaluation scores between the virtual characters. Therefore, one can select virtual characters 196 from this database based on the degree of differences between each other in terms of scores, 197 but also based on their proximity.

198



Fig 3. Silhouette Plot. Ordered silhouette width for each virtual character in their cluster. The
 red Dashed line represents the average silhouette width (0.44).

203

204 To our knowledge, ATHOS is the first database of non-emotional virtual characters, 205 freely available online and providing details about design and evaluation. In some previous 206 studies using immersive virtual environment, either little information was provided regarding 207 the design of the virtual characters [5,11,12], or virtual characters were taken from websites 208 proposing only a few visual attributes often with poor design styles and brief descriptions [13]. 209 In this context, ATHOS database may represent a valuable tool in VR research as well as 210 applied domains as it is freely available, and includes validated evaluation of realistic visual 211 characters. Indeed, the feeling of social presence in immersive environments seems to depend 212 on the realism of the virtual stimuli [2]. As evidence, Iachini and colleagues [14] revealed an 213 increase of comfort distance in social interactions when using virtual robots instead of virtual characters. In the same vein, Fini and colleagues [15] showed that human virtual characters can 214

be used as allocentric frame of reference but not virtual wooden dummies. Furthermore,
ATHOS database, combined with head-mounted display, may offer new research avenues in
studies looking for an easy to carry installation. The ATHOS database thus offers a number of
advantages for virtual reality providing more immersive stimuli and more social presence than
simply using videos displayed on a computer screen [16] or bulky virtual reality equipment
[12,17–19].

221

## 222 Conclusion

223 In conclusion, ATHOS database represents the first validated freely available database 224 of male and female Caucasian virtual characters for researches and applications using 225 immersive virtual reality. Furthermore, virtual characters in ATHOS database are compatible with open access software such as Unity or Mixamo, making thus possible their implementation 226 227 in a virtual environment with specific gait or animation usually also freely available 228 (https://unity.com/). Thus, the ATHOS database paves the way for future research programs in 229 immersive virtual environments, encouraging the development of innovative scenario with 230 improved social presence and enhance potentiality for outcome replicability.

231

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- 294 Supporting information

S1 Table: Overview Table. Mean, standard deviation, number of missing evaluations, and corrected mean computed from the inter-rater reliability analysis for each virtual character as a function of the four evaluation criteria: valence (val), reliability (rel), sympathy (sym) and sociability (soc). For each virtual character, their gender and parent cluster are also provided

										Nu	mber	of Miss	sing					
Virtual		Mean			Standard Deviation				eval	uation		ICC						
Character	Gender	Val	Rel	Sym	Soc	Val	Rel	Sym	Soc	Val	Rel	Sym	Soc	Val	Rel	Sym	Soc	Cluster
F01	F	5.38	5.39	5.65	5.51	1.98	1.96	1.93	2.31	1	2	2	1	5.4	5.35	5.67	5.52	2
F02	F	4.89	5	4.83	5.58	2.27	2.6	2.54	2.42	2	2	2	0	4.85	5.04	4.85	5.58	2
F03	F	4.16	4.35	4.5	4.1	2.06	2.25	2.45	2.23	1	1	2	1	4.14	4.38	4.48	4.1	3
F04	F	4.86	5.16	5.15	4.99	2.38	2.21	2.25	2.17	1	3	4	1	4.88	5.13	5.14	5	2
F05	F	4.05	3.92	3.82	4.51	2.28	2.3	2.23	2.29	4	3	4	4	4.09	3.97	3.79	4.48	3
F06	F	5.52	5.69	5.64	5.89	1.67	1.62	1.71	1.82	0	1	0	0	5.53	5.63	5.63	5.88	1
F07	F	4.67	4.86	4.76	4.62	1.98	2.22	2.46	2.13	3	0	2	0	4.71	4.9	4.76	4.62	2
F08	F	4.67	4.85	5.17	5.12	2.24	2.19	2.35	2.19	3	4	3	4	4.7	4.8	5.13	5.01	2
F09	F	4.94	4.68	4.47	4.84	2.15	2.17	2.25	1.91	4	5	3	4	4.91	4.59	4.51	4.87	2
F10	F	5.68	5.35	5.72	5.75	1.85	2.14	1.91	2.15	0	0	0	0	5.68	5.39	5.71	5.75	1
F11	F	3.8	3.34	3.35	3.6	2.04	1.64	1.58	1.73	2	5	4	1	3.81	3.26	3.39	3.6	3
F12	F	3.82	3.82	3.74	3.89	2	1.85	1.65	1.87	5	4	3	4	3.83	3.77	3.71	3.8	3
F13	F	4.54	4.5	4.71	4.72	2.23	2.44	2.34	2.42	3	6	5	2	4.6	4.44	4.79	4.75	2
F14	F	3.62	3.29	3.19	3.64	1.93	1.86	1.83	2.26	4	7	6	5	3.65	3.33	3.17	3.65	3
F15	F	3.68	3.7	3.59	4.35	2.13	2.32	2.33	2.28	4	5	4	5	3.66	3.64	3.63	4.29	3
F16	F	4.26	4.72	4.3	4.81	2.22	2.13	2.28	2.06	3	4	4	3	4.31	4.8	4.29	4.82	2
F17	F	6.17	6.06	6.28	6.54	1.98	1.79	2.06	2.35	0	1	0	0	6.17	6.01	6.27	6.54	1
F18	F	4.12	4.54	4.18	3.91	2.18	2.23	1.98	2.06	6	8	9	5	4.19	4.61	4.23	3.95	3
F19	F	5.24	5.54	5.72	5.28	1.67	1.76	2.21	1.81	2	2	1	1	5.26	5.6	5.72	5.29	2
F20	F	5.04	5.01	5.21	5.21	1.88	1.8	2.11	2.33	1	2	1	1	5.05	4.96	5.18	5.22	2
F21	F	5.71	5.59	5.84	5.82	2.02	2.18	2.26	2.37	1	3	2	2	5.73	5.56	5.84	5.82	1
F22	F	5.71	5.56	5.5	5.62	1.76	2.11	2.05	2.06	0	3	1	1	5.71	5.51	5.51	5.61	1
F23	F	4.47	4.58	4.54	4.96	1.95	2.3	2.09	1.96	4	3	4	3	4.45	4.66	4.54	4.96	2
F24	F	4.21	4.33	4.02	4.47	2.01	2.09	1.87	2.26	4	3	4	4	4.25	4.42	4.05	4.56	3
M01	М	6.35	5.84	6.52	6.43	1.71	2	1.69	1.87	1	1	0	0	6.32	5.88	6.5	6.43	1
M02	М	6.03	5.7	6.44	6.4	1.88	1.94	1.84	1.93	2	3	1	1	6	5.66	6.44	6.43	1

																		_
M03	Μ	4.52	4.1	4.58	4.41	2.23	2.06	2.33	2.25	4	2	1	0	4.49	4.13	4.55	4.41	3
M04	Μ	4.48	4.47	5.13	4.8	1.49	2.19	1.94	2.13	3	3	2	0	4.49	4.52	5.14	4.79	2
M05	Μ	5.53	4.86	5.75	5.1	2.13	2.3	2.31	2.27	2	2	2	1	5.51	4.91	5.78	5.11	2
M06	Μ	6.7	6.17	6.78	7	1.64	1.94	1.82	1.87	2	3	2	2	6.73	6.14	6.79	7.04	1
M07	Μ	6.98	6.58	7.02	7.12	1.37	1.95	1.6	1.75	1	1	0	0	6.94	6.52	7	7.12	1
M08	Μ	4.15	3.75	4.04	4.22	1.9	2.03	2.11	2.11	4	4	3	4	4.14	3.73	4.07	4.2	3
M09	Μ	4.63	4.82	5.3	5.15	2.2	2	2.09	2.11	1	3	1	2	4.65	4.8	5.31	5.08	2
M10	Μ	6.39	6	6.66	6.52	1.79	1.67	1.49	1.78	1	1	0	0	6.36	5.94	6.65	6.52	1
M11	М	5.3	4.39	5.07	5.38	2.1	2.33	2.27	2.38	2	2	1	1	5.34	4.45	5.07	5.38	2
M12	Μ	4.6	4.3	4.81	4.68	1.46	1.73	1.9	1.79	0	2	0	0	4.6	4.35	4.8	4.67	2
M13	М	5.38	4.84	5.4	5.35	1.81	2.03	2.18	1.94	2	1	1	1	5.35	4.89	5.41	5.37	2
M14	Μ	4.21	4.15	4.66	3.76	1.91	2.01	2.3	2.04	0	1	2	2	4.22	4.2	4.67	3.77	3
M15	Μ	5.06	4.96	5.11	5.16	2.26	2.14	2.38	2.3	1	1	0	0	5.02	5	5.1	5.16	2
M16	Μ	4.87	4.81	5.05	4.77	1.91	1.81	1.99	2.17	3	3	1	2	4.83	4.77	5.06	4.8	2
M17	М	5.74	5.39	5.85	5.9	1.92	2.15	1.99	1.99	3	2	1	1	5.74	5.45	5.86	5.93	1
M18	Μ	4.26	3.88	4.74	4.45	1.65	1.57	1.87	2.03	3	2	2	3	4.22	3.82	4.65	4.39	3
M19	М	4.99	3.95	4.57	5.07	1.84	1.95	2.16	2.24	3	4	2	3	4.89	3.93	4.51	5.01	2
M20	Μ	4.64	4.45	4.91	4.6	1.75	1.65	1.92	1.91	2	4	2	3	4.65	4.39	4.92	4.63	2
M21	М	6.74	6.18	7.23	6.35	1.71	2.21	1.55	2.08	1	0	0	0	6.71	6.22	7.22	6.35	1
M22	Μ	4.88	4.23	4.75	4.95	1.36	1.77	1.55	1.86	5	4	4	4	4.92	4.2	4.76	4.99	2
M23	Μ	5.44	4.85	5.36	5.4	2.12	2.05	1.87	2.08	2	1	1	2	5.41	4.9	5.36	5.45	2
M24	М	5.55	5.82	6.17	5.69	1.64	1.54	1.65	1.82	2	3	1	1	5.53	5.79	6.18	5.71	1