D ing he igh hing: A c mm n ne al ci c i f a ia e i len c m a i na e beha i

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H man ha e a c n ide able facili ada hei beha i in a manne ha i a ia e cial cie al c n e . A fail e f hi abili can lead cial e cl i n and i a fea e f di de ch a ch a h and di i e beha i di de . We in e iga ed he ne al ba i f hi abili ing a c mi ed ide game la ed b 12 heal h a ici an in an fMRI canne . T c ndi i n in ed e eme e am le f c n e -a ia e ac i n: h ing an agg e i e h man id a ailan healing a a i e nded e n. T c n l c ndi i n in ed ca ef ll ma ched im i ai ed i h ina i- a e ac i n : h ing he e n healing he a ailan . S i ingl , he ame ci c i , incl ding he am gdala and e m medial ef n al c e , a ac i a ed hen a ici an ac ed in a c n e -a ia e manne , he he being c m a i na e a d an inj ed c n ecific agg e i e a d a i len a ailan . The finding indica e a c mm n em ha g ide beha i al e e i n a ia e cial

responses in healthy individuals: an fMRI study reporting frontal involvement in the expression of imagined aggressive behavior (Pietrini et al., 2000). Relatively little previous work has

We compared the neural response to shooting assailants and healing casualties (the appropriate behavior conditions within our video game-like context) with the neural response to matched conditions of healing assailants and shooting casualties (inappropriate behaviors within our context). Significant activations in this comparison (summarized in Fig. 2, see Materials and methods)

It is important to note that the involvement of the amygdala-

response might also be a consequence of the engagement of the participant's emotional response and amygdala activation. Although memory was not tested in the current study, this explanation would predict that this hippocampal activity would be reflected in improved recall for these events (Cahill, 2000; Hamann, 2001; Hamann et al., 1999).

In conclusion, our results suggest that the expression of context-appropriate behavior in healthy participants is guided by a common neural system including the amygdala and ventromedial prefrontal cortex. These data support suggestions that dysfunction in this system underlies the presentation of inappropriate social behavior in some individuals (Blair and Cipolotti, 2000; Damasio, 1994; Davidson et al., 2000; Grafman et al., 1996). The paradigm presented here provides a way to begin to investigate the neural bases of socially appropriate behavior, how they fail in conditions such as psychopathy, and how this system is affected by manipulation of the (virtual) contexts encountered, or of the prior experience or pharmacological state of the subject.

Ackn ledgmen

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Refe ence

Amaral, D.G., 2002. The primate amygdala and the neurobiology of social behavior: implications for understanding social anxiety. Biol. Psychiatry 51, 11–17.

Amaral, D.G., Price, J.L., 1984. Amygdalo-cortical projections in the monkey ( ). J. Comp. Neurol. 230, 465–496.

Anderson, S.W., Bechara, A., Damasio, H., Tranel, D., Damasio, A.R., 1999. Impairment of social and moral behaviour related to early damage in human prefrontal cortex. Nat. Neurosci. 2, 1032–1037.

Aron, A.R., Robbins, T.W., Poldrack, R.A., 2004. Inhibition and the right inferior frontal cortex. Trends Cogn. Sci. 8, 170–177.

Berthoz, S., Armony, J., Blair, R.J.R., Dolan, R., 2002. Neural correlates of violation of social norms and embarrassment. Brain 125, 1696–1708.

Blair, R.J.R., 2003. Neurobiological basis of psychopathy. Br. J. Psychiatry 182, 5–7.

Blair, R.J., 2004. The roles of orbital frontal cortex in the modulation of antisocial behavior. Brain Cogn. 55, 198–208.

Blair, R.J.R., Cipolotti, L., 2000. Impaired social response reversal: a case of "acquired sociopathy". Brain 123, 1122–1141.

Brett, M., Nichols, T., Andersson, A., Wager, T., Poline, J.B., 2004. When is a conjunction not a conjunction? (Poster Presented at the 10th International Conference on Functional Mapping of the Human Brain). NeuroImage, 22.

Burgess, N., Maguire, E.A., Spiers, H.J., O'Keefe, J., 2001. A temporoparietal and prefrontal network for retrieving the spatial context of lifelike events. NeuroImage 14, 439–453.

Cahill, L., 2000. Neurobiological mechanisms of emotionally influenced, long-term memory. Prog. Brain Res. 126, 29–37.

Craig, A.D., 2003. Interoception: the sense of the physiological condition of the body. Curr.Opin. Neurobiol. 13, 500–505.

Critchley, H.D., Mathias, C.J., Dolan, R.J., 2001. Neural activity in the human brain relating to uncertainty and arousal during anticipation. Neuron 29, 537–545.

Damasio, A.R., 1994. Descartes' Error: Emotion, Rationality and the Human Brain. Putnam (Grosset Books), New York.

Davidson, R.J., Putnam, K.M., Larson, C.L., 2000. Dysfunction in the neural circuitry of emotion regulation—a possible prelude to violence. Science 289, 591–594.

Dolcos, F., LaBar, K.S., Cabeza, R., 2004. Interaction between the amygdala and the medial temporal lobe memory system predicts better memory for emotional events. Neuron 42, 855–863.

Emery, N.J., Amaral, D.G., 2000. The role of the amygdala in primate social cognition. In: Lane, R.D., Nadel, L. (Eds.), Cognitive Neuroscience of Emotion. Oxford Univ. Press, New York, pp. 156–191.

Everitt, B.J., Cardinal, R.N., Hall, J., Parkinson, J.A., Robbins, T.W., 2000. Differential involvement of amygdala subsystems in appetitive conditioning and drug addiction. In: Aggleton, J.P. (Ed.), The Amygdala: A Functional Analysis. Oxford Univ. Press, Oxford, pp. 289–310.

memories depends on amygdala and hippocampus and their interactions. Nat. Neurosci. 7, 278–285.

Rilling, J., Gutman, D., Zeh, T., Pagnoni, G., Berns, G., Kilts, C., 2002. A neural basis for social cooperation. Neuron 35, 395–405.

Singer, T., Seymour, B., O'Doherty, J., Kaube, H., Dolan, R.J., Frith, C.D., 2004. Empathy for pain involves the affective but not sensory components of pain. Science 303, 1157–1162.

Suzuki, W.A., Amaral, D.G., 1990. Cortical inputs to the CA1 field of the monkey hippocampus originate from the perirhinal and parahippocampal cortex but not from area TE. Neurosci. Lett. 115, 43–48.

Whalen, P.J., Shin, L.M., McInerney, S.C., Fischer, H., Wright, C.I., Rauch, S.L., 2001. A functional MRI study of human amygdala responses to facial expressions of fear versus anger. Emotion 1, 70–83.