The investigation of neural correlates of monetary reward by using functional neuroimaging techniques

Harold Mouras

Inserm, U742, Paris, F-75005 France; Université Pierre et Marie Curie-Paris 6, UMR S 742, Paris, F-75005 France and Socio-Affective Development Group, Department of Psychology, University of Geneva, CH-1205 Geneva, Switzerland.

harold.mouras@snv.jussieu.fr

Abstract: Money is a specifically human incentive. However, functional imaging techniques bring striking evidence that neural circuits pertaining to more "natural" addictive and rewarding processes are involved in response to monetary reward. Main results are evoked here, with specific brain responses demonstrated along the different stages of the process.

With regard to a drug theory of money, Lea & Webley (L&W) address the question: "Is there a biological reason why money is such a powerful incentive?" (sect. 1.5). Interesting results related to this question have emerged from modern neuroimaging techniques, and these results have converged with studies about decision processes in fields such as neuroeconomics (Glimcher & Rustichini 2004).

Studies developed by Breiter and colleagues are of primary interest. After a focus on the effects of cocaine on brain circuits in a cocaine users sample (Breiter et al. 1997), neural circuits involved in monetary gain and losses were investigated (Breiter et al. 2001). A game of chance performed in the scanning session included an "expectation" phase where different possible monetary amounts were presented and an "outcome" with the presentation of the gain or loss. A striking result of this study was that an incentive unique to humans (i.e., money) induced brain activations in areas such as the nucleus accumbens, the sublenticular extended amygdala, and the orbital gyrus (in the prospect and outcome phases) that overlap brain activations observed in response to cocaine infusions in addicted subjects (Breiter et al. 1997) or to low doses of morphine in drug-naïve individuals (Breiter et al. 2000). Such an overlap could partly explain that a dysfunction in this cerebral network could contribute to impulse disorders, such as compulsive gambling.

The study performed by Breiter et al. in 2001 identified an overlap between cerebral areas involved in monetary rewards and those involved in drug addiction, but few differences were recorded in brain activations for different stages (e.g., the prospect and outcome phases) of cerebral processes related to monetary reward. The growing development of neuroimaging techniques has allowed several studies to focus on specific properties of the cerebral networks involved in response to monetary stimuli, and some results have identified brain activation differences occurring during different stages of the process. Based on primate work, Knutson et al. (2001a) used a parametric task that elicited anticipation of monetary reward or punishment. Within a sample of eight healthy volunteers, this study was the first to demonstrate a selective recruitment of the nucleus accumbens (a part of the ventral striatum) for monetary gain but not for loss; moreover, the activation was proportional to the amount of the reward. Most often, neuroimaging studies on the neural correlates of monetary reward have used tasks that involve prospect, choice, and outcome phases. As theses phases can be temporally close, the event-related functional magnetic resonance imaging (fMRI) method with a good temporal resolution should allow identification of specific brain activations related to these phases.

On this topic, a recent study by Ernst et al. (2004) brought very interesting results: whereas the prominent recruitment of the ventral striatum was confirmed, the choice phase involved more "cognitive" areas such as parieto-occipital ones (visuospatial attention), the dorsal part of the anterior cingulate cortex (conflict monitoring), parietal (manipulation of quantities) and premotor areas. This study also showed that high risk/reward conditions are associated with greater neural response during the choice phase but not the prospect phase. Likewise, were there specific brain activations that characterized the outcome of a monetary reward? With the same parametric task described earlier, Knutson et al. (2003) showed that a particular region of the mesial prefrontal cortex is *activated* when an expected reward is obtained, and a previous study (Knutson et al. 2001b) showed that this particular region is *deactivaed* in response to reward omission. Thus, the use of fast neuroimaging techniques would allow demonstration of a dissociation between ventral striatum areas involved in the prospect phase of the reward and more prefrontal ones involved in the outcome phase.

Clearly, neural circuits involved in the prospect and the outcome phases, although partly distinct anatomically, should be functionally linked. This point has been addressed in studies seeking to identify the reaction of monetary reward circuits when a difference occurs between the expected value and the real value of the monetary reward obtained. Still using event-related fMRI, Ramnani et al. (2004) examined cerebral activity related to the failure of expected rewards and the occurrence of unexpected rewards, independently of any goal-directed actions or decisions. Principally, this study showed that each type of prediction error evokes activity in a distinct frontotemporal circuit: whereas unexpected reward failure evokes activity in the temporal cortex and frontal pole (Brodmann area 10), unpredicted rewards evoke activity in the orbitofrontal cortex, the frontal pole parahippocampal cortex, and the cerebellum. The study also showed that the activity time-locked to prediction errors in frontotemporal circuits is involved in encoding the associations between visual cues and monetary reward. For the purpose of this commentary, this result is very important because it shows that neural mechanisms are not only temporary and activated either during the prospect phase, the stimulus presentation, or the outcome phase, but also that networks are devoted to the association between these successive phases.

Since 1999 several neuroimaging studies have explored the neural circuits involved in other goal-directed behaviors such as human sexual motivation (Mouras & Stoléru, in press; Stoléru & Mouras, in press). Following these reviews, several brain areas have been shown to be related to both monetary reward and sexual motivation. For example, most studies on neural correlates of sexual motivation have identified anterior cingulate cortex activations (often interpreted as involved in action preparatory processes), and a recent study by Williams et al. (2004) reported a similar role for monetary reward processes.

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Avoiding drug dependency

Paul Romanowich, Edmund Fantino, and Stephanie Stolarz-Fantino

Department of Psychology, University of California, San Diego, La Jolla, CA 92093-0109.

promanowich@ucsd.edu **efantino@ucsd.edu**
sfantino@psy.ucsd.edu

Abstract: If Tool Theory is buttressed by fundamental concepts of conditioned reinforcement and extinction, a dependence on Drug Theory may not be necessary.

Lea & Webley (L&W) insist that a Tool Theory of money, which encompasses only purely ontological behavior, is inadequate to deal with the profound motivational power displayed by human behavior in relation to money. In their provocative analysis, the authors depend much on the notion that money "can mimic the satisfaction both from the instinct to play and from the

instinct to trade" (sect. 5.3). Without a biological (evolutionary) basis, such motivators would be seen as "scandalous" from certain subsets of psychology. However, empirically based theories of motivation, such as the Premack Principle, explicitly state that any desirable behavior or tangible item can serve as a basis for motivation. Within this framework what qualifies for a motivator does not depend on its biological or adaptive value, but rather on the item or behavior's value in relation to all other possible behaviors or items. This idea about primary and secondary reinforcement is consistent with Skinner's behavioral position and suggests that it is unnecessary to consider Skinner's view as Drug Theory. Money has an important place in the hierarchy of value because of its flexibility. Not only can it be used to make other reinforcers available, but – like a good tool – it extends their reach, making them available at future times when they may be even more desirable than they are at present. It can be argued that computers, too, are extremely desirable tools because of their extraordinary flexibility; one notebook computer can replace a roomful of equipment. And, like money, computers are the objects of a great deal of preoccupation on the part of their users.

L&W also assert that token reinforcers maintain their motivational power without explicit pairings with unconditioned reinforcers. Indeed, such reinforcers can exert motivational influence even when devalued or when presented in a different context (e.g., Fantino 2000; O'Daly et al., in press). However, such influence is typically fleeting. In fact, the authors point out that in many historical societies where rapid devaluation of currency occurred, the old devalued currency was abandoned and either money with a stable value was used or bartering ensued. This devalued money could then be used as a more literal "tool" as in Figure 1, which shows a woman in post-WWI Germany using a pile of devalued Marks as kindling.

Figure 1 (Romanowich et al.). Inflation – 1923. Devalued Marks are used as kindling in post-WWI Germany.

Extinction is a key component in the process of operant conditioning. When one tangible item or behavior leads to unconditioned or conditioned reinforcers, those tangible items or behaviors will be motivators. Other equally tangible items or behaviors that do not, or no longer, lead to reinforcers will not be motivators. This means-ends relationship is identical to Tool Theory. Drugs are no different in this respect. Once a drug no longer offers any physiological satisfaction, its use stops. This chemical action is biological, but obviously has no evolutionary advantage to the individual. In most cases, as the authors point out, the opposite effect can be observed. But, other conditioned stimuli may still elicit the craving for the drug. Presenting these conditioned stimuli without the drug also causes a decrease in that response. Therefore, drugs can also be thought of in a means-ends analysis when the concept of extinction is considered.

The proposition that seemingly ubiquitous human behavior can be explained in evolutionary terms (instincts) has led to gross overgeneralizations throughout the history of psychology (for a discussion, see Fantino & Logan 1979, pp. 297–301). There is no doubt that the ontological biology of a person will change in response to the use of money or tokens (i.e., changes in neural circuitry will occur). But neural changes accompanying conditioning do not require Drug Theory. Tools, be they money or computers, are likely to be powerful generalized reinforcers since, as discussed above, they are paired with so many good things. A broadened concept of generalized reinforcers together with the concept of extinction can go a long way to making a dependence on Drug Theory superfluous.

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The image shown in Figure. 1 is "Inflation-1923.jpg," produced by AdsD der Friedrich-Ebert-Stiftung. The preparation of this commentary was supported by National Science Foundation Grant IBN-9870900.

Evolutionary psychology and functionally empty metaphors

Don Ross[a,b] and David Spurrett[c]

[a]*Departments of Philosophy and Economics, University of Alabama at Birmingham, Birmingham, AL 35294-1260, and* [b]*School of Economics, University of Cape Town, Rondebosch 7701, South Africa;* [b]*School of Philosophy and Ethics, University of KwaZulu-Natal, Howard College Campus, Durban, 4041, South Africa.*

dross@commerce.uct.ac.za

http://www.uab.edu/philosophy/ross.html; spurrett@ukzn.ac.za

http://www.ukzn.ac.za/undphil/spurrett/

Abstract: Lea & Webley's (L&W's) non-exclusive distinction between tool-like and drug-like motivators is insufficiently discriminating to say much about money that is useful, as the distinction's equivocal application to sex, food, and drugs shows. Further, it appears as though the motivations of problem gamblers are non-metaphorically like those of drug addicts.

Lea & Webley (L&W) make clear that their topic is a choice of metaphors for money. They take care to distance themselves from the idea that one of their two favoured metaphors could be altogether "correct" at the expense of the other. So, arguing against them that money is not a drug but (more like) a tool, might seem to miss their point. We instead raise doubts about the *value* of their dichotomy of metaphors in the first place. We then say *why* there is indeed an interesting, but non-metaphorical, relationship between drugs and money.

L&W's discussion depends on a distinction between motivators that directly subserve biological functions (tools) and what they call (in sect. 2.2.4) "functionless motivators" (drugs). They recognize that money serves some biological functions much of the time and so is, to that extent, a tool. But then they argue