Blood Levels of Serotonin Are Differentially Affected by Romantic Love in Men and Women

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Abstract. People who are in love think about their beloved the whole day, which is supposed to be associated with serotonin. The research questions were how peripheral serotonin levels differ between individuals that are in love compared to individuals that are not in love, and how these levels are associated with obsessive thinking about the beloved. Because gender differences exist in romantic love and in the serotonergic system, gender differences were tested. Twenty participants who were in love (10 men) and 20 who were not in love (10 men) completed several questionnaires, and plasma and serum serotonin levels were assessed. The men who were in love had lower serotonin levels than the men who were not in love, while women showed the opposite pattern. The participants that were in love reported obsessive thinking about their beloved for 65% of their waking hours. In women, obsessive thinking about the beloved was associated with an increased serotonin level in serum. The serotonergic system seems to play a role in romantic love, but the effects appear opposite for men and women.

Keywords: serotonin (5-HT), romantic love, gender differences, obsessive thinking

People who are in love and patients with obsessive-compulsive disorder (OCD) resemble each other in the sense that they both have obsessions. In general, obsessions are ideas that haunt, hover, and constantly invade one’s consciousness (Reber & Reber, 2001). Specifically, OCD patients spend a lot of time thinking about their doubts and fears (APA, 2000), whereas individuals that are in love think about their beloved almost whole day (Fisher, Aron, Mashek, Li, & Brown, 2002). OCD symptoms can be relieved by selective serotonin reuptake inhibitors (SSRIs) such as fluoxetine (Greist et al., 2003), which suggests that OCD is accompanied by a dysfunction in the serotonergic system (Insel, Mueller, Alterman, Linnoila, & Murphy, 1985; Lucki, 1998). This notion, and the resemblance between OCD and romantic love in terms of obsessive thinking, have led to the hypothesis that romantic love is accompanied by reduced levels of serotonin (5-hydroxytryptamine, 5-HT) (Fisher, 1998; Fisher et al., 2002).

Interestingly, Kurup and Kurup (2003b) have observed that individuals with a predisposition to fall in love had lower blood plasma serotonin levels than did individuals without such predisposition, as evident from the fact that they had never fallen in love and had a conventional, arranged Indian marriage. Although this study suggests that serotonin levels are associated with the tendency to fall in love (i.e., trait love), it does not reveal how serotonin levels are related to being in love (i.e., state love).

Marazziti, Akiskal, Rossi, and Cassano (1999) have examined differences in the serotonergic system between individuals that were in love and individuals that were not in love. They have shown that the density of the serotonin transporter in blood platelets was lower in the participants that were in love than in the participants that were not in love. Notably, when the participants that were in love were tested again about a year later, their serotonin transporter density had returned to levels equivalent to the participants that were not in love, which suggests that romantic love is accompanied by a transient change in the serotonergic system. Moreover, Marazziti et al. have also compared the serotonin transporter density in the participants that were in love with the transporter density in OCD patients, and found that these were undistinguishable. This finding lends support to the notion that the altered serotonergic system during romantic love may actually be related to obsessive thinking about the beloved (see also Langeslag, 2009). Note, however, that the serotonin transporter is a membrane protein that transports serotonin from the blood plasma back into the blood platelets. On the one hand, a reduction of transporter density can thus be expected to be accompanied by an increased plasma serotonin level during romantic love.
On the other hand, a reduction of transporter density may also be a compensatory reaction in response to a decreased blood plasma level during romantic love. The relation between the serotonergic system, being in love, and obses-
sive thinking about the beloved thus remains unclear.

When considering the relationship between the seroton-
nergic system and romantic love, it is the central rather than
the peripheral serotonergic system that is of interest. Unfor-
lunately, the central serotonergic system is also much more
difficult to probe in healthy human volunteers, for both prac-
tical and ethical reasons. Peripheral serotonin is synthesized
mainly in the gastrointestinal tract and lungs, stored in blood
platelets, and is involved in smooth muscle contraction (Linder et al., 2007). Central serotonin is synthesized mainly
in the raphe nuclei, stored in nerve cells, and involved in
mood, sleep, appetite, and sexual behavior, for example
(Lucki, 1998). Nevertheless, previous studies have shown
that the peripheral serotonergic system can be taken as a
model for the central serotonergic system to a certain degree.

The density of the serotonin transporter on blood platelets
has been shown to be linked to the density of this transporter
on neurons in the brain (Rausch et al., 2005). Likewise, sig-
ificant correlations exist between the markers of serotonin
in blood and those markers in cerebrospinal fluid (Sarrias,
Cabré, Martínez, & Artigas, 1990).

In studies regarding other mental states/disorders, such as
defense, conduct disorder, autism, eating disorders, and
suicidal tendencies, the association between these mental
states/disorders and the neurotransmitter serotonin has been
tested using different peripheral serotonin measures,
including the plasma serotonin level and the serum serotonin
level (Croonenberghs et al., 2000; Golubchik, Mozes,
Vered, & Weizman, 2009; Kurup & Kurup, 2003a; Sarrias
et al., 1987; Spivak et al., 2004; Tyano et al., 2006). About
99% of circulatory serotonin is contained within blood plate-
lets and the remaining 1% is free serotonin in the blood
plasma. It has been suggested that this plasma serotonin
level represents the level of serotonin present in the synaptic
clefts in the brain that is available for binding to serotonin
receptors on neurons (Stahl, 1977). As the serum serotonin
level reflects the intraplatelet concentration of serotonin, this
parameter may be taken as a measure of intracellular central
serotonin.

The goal of the present study was to determine the asso-
ciation between serotonin levels, being in love, and obses-
sive thinking about the beloved. The first research
question was whether peripheral serotonin levels differ
between individuals who experience early stage romantic
love, as compared to individuals who are currently not in
love. The second research question was whether these levels
are associated with obsessive thinking about the beloved.
Given that extracellular serotonin in the central nervous sys-
tem is thought to be reflected in the plasma serotonin level
(Sarrias et al., 1990; Stahl, 1977), we hypothesized an asso-
ciation between romantic love and the plasma serotonin
level. Furthermore, the previous finding of a reduced platelet
serotonin transporter density during romantic love (Marazziti
et al., 1999) and the notion that this transporter transports
serotonin back into the cell (e.g., platelet or presynaptic
neuron) led to the hypothesis of an association between
romantic love and the serotonin level in serum. Finally,
because gender differences exist both in romantic love (Geary,
Vigil, & Byrd-Craven, 2004; Harris, 2002; Meston & Buss,
2007) and in the serotonergic system (Cosgrove, Mazure,
& Staley, 2007), gender was taken into account in all analyses.

Methods

Participants

Two groups of participants were tested: Twenty participants
(10 male) that were in love and 20 participants (10 male)
that were not in love. The mean age of the participants
was 20.7 years (SD = 2.7, range = 18–30 years), see
Table 1 for mean age stratified by love status and gender.

Participants were recruited among the students of the Eras-
mus University Rotterdam and by word of mouth. Because
romantic love is impermanent and decreases with time
(Fisher et al., 2002; Marazziti et al., 1999), participants were
included in the love group only when they had been in
love for 9 months or less. The participants that were not
in love were not involved in any romantic relationship
and did not feel broken hearted. None of the participants
suffered from depression,1 obsessive-compulsive disorder,

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Table 1. Means (standard deviations in brackets) of several variables stratified by love status and gender

<table>
<thead>
<tr>
<th></th>
<th>In love</th>
<th>Not in love</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Men (n = 10)</td>
<td>Women (n = 10)</td>
</tr>
<tr>
<td><strong>Age (years)</strong></td>
<td>21.3 (2.7)</td>
<td>19.7 (2.3)</td>
</tr>
<tr>
<td><strong>Frequency previous love</strong></td>
<td>3.9 (3.0)</td>
<td>2.2 (1.8)</td>
</tr>
<tr>
<td><strong>Intensity previous love (possible range = 1–9)</strong></td>
<td>6.6 (1.2)</td>
<td>7.6 (1.3)</td>
</tr>
<tr>
<td><strong>Frequency previous relationships</strong></td>
<td>1.9 (1.2)</td>
<td>1.0 (0.7)</td>
</tr>
<tr>
<td><strong>Duration previous relationships (months)</strong></td>
<td>6.3 (4.1)</td>
<td>27.5 (26.9)</td>
</tr>
<tr>
<td><strong>Obsessive and compulsive behavior (possible range = 32–160)</strong></td>
<td>63.8 (9.4)</td>
<td>58.5 (11.8)</td>
</tr>
</tbody>
</table>

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1 Participants were considered nondepressed if they scored 13 or less on the Beck Depression Inventory (Beck, Ward, Mendelson, Mock, & Erbaugh, 1961; Lasa, Ayusi-Mateos, Vázquez-Barquero, Díez-Manrique, & Dowrick, 2000).
hypercholesterolemia, or hypertension. None of the participants used antidepressants, serotonin-reuptake inhibitors, statins, or antihypertensives. The study has been carried out in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of the Erasmus Medical Center. Participants provided written informed consent prior to testing and were remunerated with either course credit or 5 Euros.

Procedure

Because of the circadian rhythm of the serotonergic system (Ortiz, Artigas, & Gelpi, 1988; Pietraszek et al., 1991), all blood samples were drawn between 8.45 a.m. and 10.30 a.m. To control for the dietary influence on the serotonergic system (Ortiz et al., 1988), all participants were instructed to have breakfast with one or two slices of bread topped with cheese, meat, or jam, and a cup of tea or coffee before testing.

The participants that were in love completed a general questionnaire about their current feelings of romantic love (i.e., state love) (Langeslag, Franken, & Van Strien, 2008; Langeslag, Jansma, Franken, & Van Strien, 2007). They rated the extent to which they experienced romantic love with the beloved on a 9-point Likert scale (self-reported love intensity; 1 = not in love at all, 9 = very much in love). They further rated for how much of the time of their waking hours they tended to think about their beloved. Participants placed a mark on a 10 cm horizontal line that ranged from “not at all” at the left end to “the entire time” at the right end. The number of millimeters from the left end was taken as the percentage of waking hours (self-reported obsessive thinking). Participants also reported for how many months they had been in love (love duration), as well as for how many months they had been involved in any romantic relationship with their beloved (relationship duration). The participants that were in love further completed the Passionate Love Scale (PLS; Hatfield, 1998), which assesses the extent to which someone experiences passionate or romantic love (PLS love intensity; minimum mean score = 1, maximum = 9). Items 5, 19, and 21 specifically measure the extent of intrusive thinking about, or preoccupation with the beloved, and the mean of these three items was taken as an additional measure of obsessive thinking about the beloved (PLS obsessive thinking).

To control for differences in the tendency to fall in love (i.e., trait love), all participants reported how often they had been in love before (frequency previous love), how intense those love experiences were on average (intensity previous love), how often they had been involved in a romantic relationship before (frequency previous relationships), and what the average duration of those relationships was (duration previous relationships). Furthermore, all participants completed a Dutch questionnaire on obsessive and compulsive behavior (Inventarisatielijst Dagelijkse Bezigheden) (obsessive and compulsive behavior) (Kraaimaat, 1994; Kraaimaat & Van Dam-Baggen, 1976). Following, blood was drawn by venapuncture (7 ml in an EDTA-containing tube and 8 ml in an anticoagulant-free tube) for assessment of serotonin levels in blood plasma and blood serum, respectively. The total testing session lasted approximately 20–30 min.

Biochemical Analysis

Platelet-poor plasma and serum were prepared after centrifugation of the blood at 2650 × g for 20 min at 20 °C. The concentrations of serotonin in plasma and serum were measured in duplicate by high-performance liquid chromatography employing electrochemical detection (detection limit in plasma: 1 nM). Quantification was done by measuring peak heights and absolute concentrations were calculated using a combined external and internal standard (applying z-methyl 5-HT method). The mean recovery (±SD) of serotonin added to the plasma samples was 95 ± 7% (n = 76) (Fekkes, Timmerman, & Pepplinkhuizen, 1997).

Statistical Analyses

The questionnaires that were filled out only by the participants that were in love were analyzed with one-way ANOVAs with the factor Sex (male, female). The other questionnaires and the biochemical data were analyzed with 2 × 2 ANOVAs with factors Love (in love, not in love) and Sex (male, female). A significance level of 5% (two-sided) was selected. Significant interaction effects were followed up by independent samples t-tests as post hoc comparisons. Correlations between the different measures were computed.

Results

Current Love and Relationship

All but three of the participants (two males and one female) that were in love had a beloved of the opposite sex. The participants’ self-reported love intensity was 7.9 (SD = 1.9, range = 5–9). The mean duration of the participants’ love was 4.6 months (SD = 2.4, range = 1.0–9.0). All but five (four males and one female) of the participants that were in love were involved in a romantic relationship with their beloved and the mean duration of these relationships was 5.1 months (SD = 1.9, range = 1.8–8.5). The mean PLS love intensity of all participants that were in love was 6.8 (SD = 1.0, range = 3.6–8.1).

See Table 2 for the scores on these measures of current love and relationship for the men and women that were in love separately. Women that were in love reported to be more intensely in love than the men that were love did. The men and women that were in love did not differ from each other on any of the other characteristics regarding current love.
Previous Love and Relationships

See Table 1 for the scores on the questionnaires that were filled out by all participants. For some of the measures of previous love and relationships, the main effect of Sex was significant. Women tended to have been in love less frequently than men, $F(1, 36) = 3.7, p = .062$, but reported greater intensity of these previous love episodes than men, $F(1, 36) = 4.9, p = .045$. Men and women had had a comparable number of previous relationships, $F(1, 36) < 1, ns$, although women’s relationships had longer durations, $F(1, 25) = 8.1, p = .009$. For none of the measures of previous love and relationships, the main effect of Love or the Love $\times$ Sex interaction reached significance, all $F$s < 2.7, all $p$s > .11, indicating that all of the observed gender differences occurred irrespective of current love status.

Serotonin

With respect to the serotonin level in blood plasma, a significant Love $\times$ Sex interaction was observed, $F(1, 36) = 10.0, p = .003$. Post hoc comparisons showed that men that were in love had a lower plasma serotonin level than men that were not in love, $t(18) = 2.8, p = .012$, while women that were in love tended to have a higher plasma serotonin level than women that were not in love, $t(18) = 1.9, p = .078$. Men that were in love had a lower plasma serotonin level than women that were in love, $t(18) = 2.5, p = .028$, whereas men that were not in love tended to have a higher plasma serotonin level than women that were not in love, $t(18) = 1.9, p = .068$, see Figure 1. The main effects of Love or Sex were not significant, both $F$s < 1, ns.

With respect to the serotonin level in blood serum, the Love $\times$ Sex interaction almost reached significance, $F(1, 36) = 3.0, p = .090$. Post hoc comparisons showed that men that were in love tended to have a lower serum serotonin level than men that were not in love, $t(18) = 1.8, p = .089$. Men that were in love had a lower serum serotonin level than women that were in love, $t(18) = 3.0, p = .008$, see Figure 2. The other post hoc comparisons were not significant, all $p$s > .10. The main effects of Love or Sex were not significant, both $F$s < 2.6, both $p$s > .12.

Obsessive Thinking

The men and women that were and were not in love did not differ in obsessive and compulsive behavior in general, all $F$s(1, 36) < 1.7, all $p$s > .20, see Table 1. Mean self-reported obsessive thinking about the beloved was 65% of waking hours ($SD = 17$, range = 27–93) and the mean PLS obsessive thinking was 5.8 ($SD = 1.6$, range = 2.0–8.0). See Table 2 for the scores on these measures for men and women separately. Men and women that were in love did not differ in obsessive thinking about the beloved.

In women that were in love, a higher score on PLS obsessive thinking was associated with higher serum serotonin levels, $r(8) = .70, p = .025$. None of the other

### Table 2. Characteristics of the participants that were in love (means and standard deviations in brackets), stratified by gender, and the $F$, degrees of freedom ($df$) and $p$ values associated with gender differences

<table>
<thead>
<tr>
<th></th>
<th>Men ($n = 10$)</th>
<th>Women ($n = 10$)</th>
<th>$F$</th>
<th>$df$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-reported love intensity (possible range = 1–9)</td>
<td>7.3 (1.2)</td>
<td>8.4 (0.7)</td>
<td>6.6</td>
<td>1, 18</td>
<td>.019</td>
</tr>
<tr>
<td>Love duration (months)</td>
<td>3.8 (2.6)</td>
<td>5.4 (2.0)</td>
<td>2.3</td>
<td>1, 18</td>
<td>.14</td>
</tr>
<tr>
<td>Relationship duration (months)</td>
<td>5.5 (2.1)</td>
<td>4.8 (1.8)</td>
<td>&lt; 1</td>
<td>1, 13</td>
<td>ns</td>
</tr>
<tr>
<td>PLS love intensity (possible range = 1–9)</td>
<td>6.5 (1.1)</td>
<td>7.2 (0.9)</td>
<td>2.1</td>
<td>1, 18</td>
<td>.17</td>
</tr>
<tr>
<td>Self-reported obsessive thinking (% of waking hours)</td>
<td>63 (20)</td>
<td>66 (14)</td>
<td>&lt; 1</td>
<td>1, 18</td>
<td>ns</td>
</tr>
<tr>
<td>PLS obsessive thinking (possible range = 1–9)</td>
<td>5.8 (2.0)</td>
<td>5.7 (1.2)</td>
<td>&lt; 1</td>
<td>1, 18</td>
<td>ns</td>
</tr>
</tbody>
</table>

Note. *This comparison has fewer degrees of freedom because not all participants that were in love were involved in a romantic relationship with their beloved.

**Figure 1. Plasma serotonin level.** Men that were in love had a lower plasma serotonin level than women that were in love, whereas men that were not in love tended to have a higher plasma serotonin level than women that were not in love. Men that were in love had a lower plasma serotonin level than men that were not in love, while women that were in love tended to have a higher plasma serotonin level than women that were not in love. Error bars reflect standard error of the mean. **$p < .05$, *$10 < p < .05$.**
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their offspring is really theirs, while women cannot be sure

problems men and women face. Men cannot be sure that

preferences, all of which reflect the different reproductive

in motives for engaging in sexual intercourse, and in mate

differences in romantic love include differences in jealousy,

serotonin function than men (Cosgrove et al., 2007). Gender

higher whole blood serotonin levels, and higher baseline

ences in current love, with women experiencing more

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gender differences in previous and current romantic experi-

we included participants that were in love regardless of

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peripheral serotonin levels and mental disorders/states

comparable to the sample size in other studies concerning

studies concerning the effect of romantic love on the seroto-

nin levels. Unfortunately, we cannot turn to the two previous

studies concerning the effect of romantic love on the seroto-

s (Kurup & Kurup, 2003b; Marazziti et al., 1999) for comparison, because the effect of gender was

not taken into account in those studies.

We further tested whether obsessive thinking about the

beloved is associated with the peripheral serotonin level.

On average, both men and women reported to spend as much

as 65% of their waking hours thinking about their beloved. We

found no relation between plasma and serum serotonin

levels and obsessive thinking in men, but in women,

increased obsessive thinking about the beloved was accom-

panied by an increased serum serotonin level. This finding

is opposite to the hypothesis that obsessive thinking about

the beloved would be associated with a reduced serotonin

level (Fisher, 1998; Fisher et al., 2002), but is in line with

the increased serotonin levels in women that were in love

compared to women that were not in love as observed in

the present study. Again, we do not have an explanation

for this unexpected finding. In any case, our findings show

that the involvement of the serotonergic system in romantic

love might not be as simple as has been suggested previ-

ously (Fisher, 1998; Fisher et al., 2002) and it may be clear

that more research is needed to clarify this issue.

There are several limitations to our study. The first is the

relatively small sample size, which was nevertheless

comparable to the sample size in other studies concerning

peripheral serotonin levels and mental disorders/states

(Croonenberghs et al., 2000; Spivak et al., 2004). Also,

we included participants that were in love regardless of

the reciprocity of the love, and regardless of the sex of their

beloved. It would be interesting to examine the effects of

different types of romantic love (such as reciprocated, unre-

ciprocated, heterosexual, homosexual) on the serotonergic

system in future studies. Another limitation is that we found

gender differences in previous and current romantic experi-

ences. We would like to argue, however, that the gender dif-

ferences in previous experiences cannot account for the

observed gender differences in serotonin levels, because

the former occurred irrespective of whether the male and fe-

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served gender differences in serotonin levels, because the ef-

effect of love on serotonin levels was opposite, instead of

smaller, in men than in women. Finally, we measured

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tonergic system ( Sarrias et al., 1990; Stahl, 1977), but obvi-

ously only to a limited degree. In addition, studying the

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plexity of the central serotonergic system, with its multiple

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association between serotonin levels in the brain and feel-

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by manipulating central serotonin levels.

![Figure 2. Serum serotonin level. Women that were in love had higher serum serotonin levels than men that were in love, and men that were not in love tended to have a higher serum serotonin levels than men that were in love. Error bars reflect standard error of the mean. **p < .05. *0.10 < p < .05.](image-url)

correlations between blood serotonin levels and self-

reported or PLS obsessive thinking were significant,

−.23 < all rs(8) < .51, all ps > .13. In men that were in

love, no significant correlations were observed between

blood serotonin levels and self-report or PLS obsessive

thinking, −.40 < all rs(8) < .03, all ps > .25.

Discussion

The goal of this study was to examine whether romantic

love and obsessive thinking about the beloved are associated

with peripheral levels of serotonin. We show here, for the

first time, that state romantic love is accompanied by differ-

ences in the peripheral level of serotonin and that gender dif-

ferences exist.

We found that men that were in love had lower plasma

and serum serotonin levels than men that were not in love.

The reverse effect was observed in women, as women that

were in love had higher plasma serotonin levels than women

that were not in love. The presence of a gender difference in

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2007). In the current study, women reported more intense

state and trait romantic love than men. Despite the known
Besides serotonin, several other neurotransmitters and neuropeptides, such as noradrenaline, dopamine, oxytocin, and vasopressin, are thought to be involved in romantic love (Aron et al., 2005; Carter, 1998; Fisher, 1998; Fisher et al., 2002; Stein & Vythilingum, 2009). Evidence for the role of these neurotransmitters and neuropeptides in human romantic love remains extremely limited, however, for both ethical and practical reasons. It remains to be investigated whether other neurotransmitters and neuropeptides than serotonin are involved in obsessive thinking about the beloved. It also remains to be examined which neurotransmitters and neuropeptides are involved in other “symptoms” of romantic love, such as increased attention for the beloved (Langeslag et al., 2007, 2008).

To conclude, men that were in love had lower peripheral serotonin levels than men that were not in love, while the opposite pattern was found for women. The participants that were in love displayed obsessive thinking about the beloved, which was associated with a higher serotonin level in women only. Our findings show that the serotonergic system plays a role in romantic love in general and in obsessive thinking about the beloved in particular, and that gender differences are present.

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