How deep can unconscious information be processed? A meta-analysis

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Wim Van den Noortgate & Bert Reynvoet
Introduction

• Can unconsciously presented information influence our behaviour?

→ Masked priming paradigm (Marcel, 1983)
# Introduction

Masked priming paradigm

<table>
<thead>
<tr>
<th>Prime</th>
<th>Target</th>
<th>Congruent/Related condition</th>
<th>Incongruent/Unrelated condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>cat</td>
<td>Both animals</td>
<td>Faster RTs</td>
<td>Slower RTs</td>
</tr>
<tr>
<td>chair</td>
<td>1 animal, 1 obj</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[
\text{Difference (RT}_I - \text{RT}_C) = \text{priming effect}
\]
Introduction

• Can unconsciously / subliminally presented information influence our behaviour? **YES!**
• BUT… what are the limits/possibilities of unconscious processing?
  – Can unconscious information be processed up to a semantic level?
  – Which factors moderate unconscious processing?
Introduction

- 2 classes of theories:
  - **Semantic accounts**: Subliminal primes are semantically processed, cf. Supraliminal primes (e.g. Dehaene et al., 1998)
  - **Non-semantic S-R accounts**: Subjects can learn to automatically associate stimuli with the adequate responses, creating **Stimulus-Response (S-R) links** (e.g. Damian, 2001)
2. S-R account → Limited to:
   - expected stimuli (e.g. repeated primes, based on task instructions)
   - Small number of stimuli (e.g. small sets, small categories)

→ NO subliminal priming expected for:
   unexpected stimuli, large stimulus sets, large stimulus categories
Aims

- How deep can subliminal stimuli be processed? ➔ Contradictory research findings and diverging accounts

- **Our aims:**
  1. Assess whether subliminal stimuli are semantically processed
  2. Assess the influence of potential moderators on subliminal semantic priming effects
Statistically combine published and unpublished data using meta-analytic techniques (Van den Bussche et al., 2009, Psych Bull)

- Search criteria:
  - Published between 1983 – 2006
  - Language: English, Dutch, French or German

- Search string:
  - (SEMANTIC OR ASSOCIATIVE) AND (PRIMING OR PRIME) AND (MASKED OR SUBLIMINAL OR UNCONSCIOUS OR AUTOMATIC)
Method

- Four databases were searched (WoS, ScienceDirect, PubMed, PsycInfo)
- Cross-references, reviews, experts
- **749 published articles** were selected
- Two independent reviewers coded these articles using 7 criteria
Method

- **Inclusion criteria:**
  1. Prime-target relation of a semantic nature in the visual domain (e.g. cat - dog)
  2. Primes had to be presented subliminally
  3. Semantic categorization, lexical decision or naming task
  4. Standard priming procedure
  5. Centrally presented single word or symbol primes
  6. Healthy sample and N>1
  7. Sufficient statistical information to compute an effect size
Method

- **46** published and **8** unpublished studies containing 156 separate conditions

- **Effect sizes** were computed:

  \[
  ES = \frac{RT\text{ (unrelated trials)} - RT\text{ (related trials)}}{SD}
  \]

  - ES = 0: no effect
  - ES > 0: positive ES (~ priming effect)
Method

- 3 standard tasks
- 2 separate meta-analyses for:
  - Conditions using a semantic categorization task → confounding response/semantic level
  - Conditions using a lexical decision or naming task → no confounding
Meta-analysis 1:
Semantic categorization conditions
### MA1: Descriptives

#### 23 studies containing 88 conditions (\(k = 88\))

<table>
<thead>
<tr>
<th>Population</th>
<th>Prime duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students: (k = 63), Adults: (k = 25)</td>
<td>(M = 42, SD = 11.2), range = 10-72</td>
</tr>
<tr>
<td>N</td>
<td>SOA</td>
</tr>
<tr>
<td>(M = 20, SD = 12.0), range = 6-80</td>
<td>(M = 106, SD = 65.3), range = 41-500</td>
</tr>
<tr>
<td>Primes</td>
<td>Masking</td>
</tr>
<tr>
<td>Symbols: (k = 32), Words: (k = 38), Both: (k = 18)</td>
<td>BPM: (k = 72), BTM: (k = 16)</td>
</tr>
<tr>
<td>Novelty</td>
<td>Visibility measured</td>
</tr>
<tr>
<td>Repeated: (k = 40), Novel: (k = 44), Both: (k = 4)</td>
<td>No: (k = 14), Yes: (k = 74)</td>
</tr>
<tr>
<td>Targets</td>
<td>Obj/Subj</td>
</tr>
<tr>
<td>Symbols: (k = 36), Words: (k = 38), Both: (k = 14)</td>
<td>Obj: (k = 57), Subj: (k = 10), Both: (k = 7) ((k = 73))</td>
</tr>
<tr>
<td>Category size</td>
<td>(d')</td>
</tr>
<tr>
<td>Small: (k = 44), Large: (k = 44)</td>
<td>(M = 0.19, SD = 0.20), range = -0.06-0.66 ((k = 58))</td>
</tr>
<tr>
<td>Target set size</td>
<td></td>
</tr>
<tr>
<td>(M = 21, SD = 23.7), range = 4-90</td>
<td></td>
</tr>
</tbody>
</table>
MA1: Empty model

- Overall mean ES = 0.80 (CI: 0.60-1.00)
- Significant differences between studies
- Significant differences between conditions, within studies

→ Look for moderators!
MA1: Moderators

- Main effects and two-way IA (no IA significant)
- Add several main effects in one model → optimal model:
  - **Prime novelty**: larger ES for repeated primes
  - **Category size**: larger ES for small categories
  - **SOA**: larger ES for longer SOAs
  - [the model slightly improved when $d'$ was added: larger ES for more visible primes]
Less priming for novel primes, large categories, short SOAs and completely invisible primes.

Still, significant priming was always observed, even under circumstances where S-R effects are less likely (novel primes / large categories).

Subliminal primes can be processed semantically!
Meta-analysis 2: Lexical decision and naming conditions
### MA2: Descriptives

#### 32 studies containing 68 conditions ($k = 68$)

<table>
<thead>
<tr>
<th>Population</th>
<th>Task</th>
<th>Lexical decision: $k = 52$, Naming: $k = 16$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students: $k = 57$, Adults: $k = 11$</td>
<td>Prime duration</td>
<td>$M = 47$, $SD = 17.9$, range = 10-84</td>
</tr>
<tr>
<td>$N$</td>
<td>SOA</td>
<td>$M = 150$, $SD = 184.4$, range = 33-784</td>
</tr>
<tr>
<td>Primes</td>
<td>Masking</td>
<td>BPM: $k = 39$, BTM: $k = 29$</td>
</tr>
<tr>
<td>$M = 33$, $SD = 26.7$, range = 9-132</td>
<td>Visibility measured</td>
<td><strong>No</strong>: $k = 30$, Yes: $k = 38$</td>
</tr>
<tr>
<td>Novelty</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Repeated: $k = 2$, Novel: $k = 66$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Targets</td>
<td>Visibility measured</td>
<td></td>
</tr>
<tr>
<td>Symbols: $k = 9$, Words: $k = 59$</td>
<td>$d'$</td>
<td>$M = 0.05$, $SD = 0.04$, range = -0.01-0.08 ($k = 4$)</td>
</tr>
<tr>
<td>Category size</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small: $k = 2$, Large: $k = 58$ ($k = 60$)</td>
<td>Obj/Subj</td>
<td></td>
</tr>
<tr>
<td>$M = 95$, $SD = 95.0$, range = 6-320 ($k = 60$)</td>
<td>$Obj: k = 27$, Subj: $k = 9$, Both: $k = 2$ ($k = 38$)</td>
<td></td>
</tr>
</tbody>
</table>
MA2: Effect sizes
MA2: Empty model

- Overall mean ES = 0.47 (CI: 0.36-0.59)
- Significant differences between studies
- NO significant differences between conditions, within studies

👉 Look for moderators!

→ 4 variables could not be included (prime format, prime novelty, category size and $d'$)
MA2: Moderators

- Main effects and two-way IA (no IA significant)
- Add several main effects in one model → optimal model:
  - **Sample size**: larger ES for smaller samples
  - **Target set size**: larger ES for larger target sets
  - **Whether or not visibility was measured**: larger ES for conditions that assessed prime visibility
  - **Prime duration**: larger ES for primes presented for a longer duration
MA2: Conclusions

- 4 variables could not be included + publication bias present: caution warranted! Future research!
- Significant priming, even under circumstances where S-R effects are less likely (lexical decision and naming)
- Subliminal primes can be processed semantically!
General Conclusions

• Can unconscious stimuli be processed in depth?
  – **YES!** Priming in conditions where S-R effects are unlikely (naming/lexical decision, semantic categorization with large categories, large target sets and/or novel primes)
  – **BUT,** S-R effects also play a prominent role (smaller ES for naming/lexical decision, novel primes, primes from large categories)

⇒ These findings reconcile the two reigning theories regarding subliminal semantic priming: when given a chance, automatic S-R effects will clearly boost priming effects. However, when S-R influences are minimized or avoided, subliminal information can be genuinely semantically processed!
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Introduction

- Semantic categorization

congruent trial:

Prime: cat
Target: DOG

More related: faster RT
Congr: faster RT
Response: press right

incongruent trial:

Prime: chair
Target: DOG

Less related: slower RT
Incongr: slower RT
Response: press right
Introduction

- Lexical decision

related trial:

Prime

\[\text{cat}\]

\[\Downarrow\]

Word!

More related faster RT

\[\Downarrow\]

Target

\[\text{DOG}\]

\[\Downarrow\]

Response = press left

unrelated trial:

Prime

\[\text{chair}\]

\[\Downarrow\]

Word!

Less related slower RT

\[\Downarrow\]

Target

\[\text{DOG}\]

\[\Downarrow\]

Response = press left

More related faster RT

Less related slower RT