Priming methods in word recognition: visual masked priming

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Roadmap

• What is priming?

• What is (visual) masked priming?
  • How does visual masked priming work?
  • What can we use visual masked priming to study?
  • How do we construct visual masked priming stimuli?

• What is DMDX?
  • How do we program a visual masked priming experiment in DMDX?
What is priming?
What is priming?

• Priming is a phenomenon where exposure to one stimulus affects the subsequent processing of another stimulus.

• Suppose that you see toucan on the way to the grocery store, and when you get there you decide to purchase Froot Loops.

• Suppose that, had you seen something else, you would have been less likely to purchase Froot Loops than another brand of cereal.

• In a very broad sense, seeing the toucan primed you to purchase Froot Loops.
What is priming?

• Priming has many applications in the world of language processing.
  • For instance, suppose you hear or read the word *nurse*. Subsequently, you might be faster to process **semantic associates** like *doctor*.
  • This suggests that *nurse* and *doctor* are connected in your lexicon, such that having processed *nurse* somehow makes *doctor* briefly more accessible.
  • Suppose you have two constructions for expressing indirect objects (e.g. “I gave the gift to Mary” vs. “I gave Mary the gift”). Hearing or reading a sentence using one construction might make you more likely to use the same type of construction in another sentence (**syntactic priming**).
  • Exposure to one construction makes it more accessible for subsequent use.
What is priming?

- Priming has many applications in the world of language processing.
- In experimental linguistics, we use priming to explore the processes underlying language use and the factors involved in word processing.
- In a priming experiment, we compare how a word (the target) is processed (e.g. how fast readers recognize it as a real word in a lexical decision task) when preceded by two different types of primes:
  - A prime which is related to the target (e.g. nurse priming DOCTOR).
  - A prime which is unrelated to the target (e.g. curse priming DOCTOR). This control prime provides the baseline against which the effect of the other prime on target processing is compared.
What is priming?

• Priming has many applications in the world of language processing.
• In experimental linguistics, we use priming to explore the processes underlying language use and the factors involved in word processing.
• Exposure to the prime may **facilitate** target processing relative to the control prime (i.e. result in faster response time (RT), higher accuracy) or **inhibit** target processing (i.e. result in slower RT, lower accuracy).
  • Both facilitation and inhibition suggest that the experimental prime interacts with the target *somehow*, but you need to interpret this interaction. Broadly:
    • **Facilitation** == the prime has preactivated the target’s lexical representation, making it easier to recognize subsequently.
    • **Inhibition** == the prime has activated other words which compete with the target, making it harder to recognize subsequently.
Go/No-go demonstration

• To demonstrate a priming effect, let’s try a go/no-go task.
  • A series of possible English words will appear onscreen, one at a time.
  • Whenever you see a real word (e.g. doctor), tap on the table with your hand as quickly as possible.
  • Whenever you see a non-word (e.g. mogtor), do nothing.
  • Lexical decision and go/no-go are similar methodologically, except that in the latter participants do not respond to one type of target.

READY?
apple
grass
blorf
stork
opta1
crote
apple
crown
shrop
trost
stork
murnt
Go/No-go demonstration

• Did you notice anything about the targets in this demonstration?

• Two of the real-word targets (*apple* and *stork*) were repeated.
  
  • Typically, language users are much faster to process a word after having been exposed to it recently before (*repetition priming*).

  • Depending on the theory of word recognition to which you subscribe, repetition priming may be accounted for (a) by a temporary increase in the resting activation level of the target (e.g. McClelland & Elman 1986), (b) by a temporary decrease in the amount of activation necessary to achieve recognition (e.g. Morton 1969), or by some other means.

  • (We’ll talk about some other types of priming effects in a bit).
Go/No-go demonstration

• In this demonstration, the first occurrence of *apple/stork* served as the prime for the second occurrence. Do you see a problem?
  • Since you were aware of both occurrences, you may notice that some words are occurring more than once and so adopt a CONSCIOUS STRATEGY of expecting repeats in completing the task.
  • As another example, what if the real-word targets included *doctor, nurse, hospital, medicine, and patient*? You might start consciously predicting that other semantic associates like *surgeon, trauma, cancer, etc.* will occur.
  • If participants notice these patterns (i.e. the relationship between prime and target) and adopt CONSCIOUS STRATEGIES for task completion, then we aren’t studying the SUBCONSCIOUS PROCESSES underlying word processing. This is a problem, which leads us to............
What is (visual) masked priming?
Supraliminal vs. subliminal/masked priming

• In our go/no-go task demonstration, the primes were presented **supraliminially** (i.e. such that you were consciously aware of them).
  • When primes are presented supraliminially, it’s possible for participants to recognize the relationship between primes and targets and so adopt conscious strategies for completing the task at hand.

• In this workshop, we will learn how to present primes **subliminally** (i.e. such that you are NOT consciously aware of them) instead.
  • Both for historical reasons and because of the negative connotations of the term *subliminal*, this is more often called **masked priming**.
  • Personally, I prefer the term *subliminal* over *masked* in explaining my work to laypeople, but *masked* is the term that the field prefers.
Supraliminal vs. subliminal/masked priming

- In a supraliminal priming experiment, either:
  - one item occurs per trial, and participants must respond to the target on each trial. The prime occurs as the target on a previous trial.
  - two items occur per trial (the prime, followed by the target), and participants must respond to the second item on each trial.

- In a subliminal/masked priming experiment:
  - both the prime and the target occur on each trial, but participants are only aware of (and so only respond to) the target.
  - Among other things, one difference is that masked priming effects are more short-lived than supraliminal priming effects.
Visual masked priming

• In a **visual masked priming** experiment, participants see three items on each trial, but they only respond to the target (Forster and Davis 1984):
  1. a **forward mask** consisting of a row of hashtags “#####”.
  2. the **prime**, which is presented in lower case (or smaller font).
  3. the **target**, which is presented in upper case (or larger font).

  Click [here](#) for a VMP demonstration in DMDX.
Visual masked priming

- If DMDX fails to open or the demonstration does not run properly, you can find video recordings of trials from a VMP study on my website.
- Note that the specifications of your monitor determines the relative timing of trial components, and so may affect how these demo trials appear.

<table>
<thead>
<tr>
<th>Repetition prime</th>
<th>table ~ TABLE</th>
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<tbody>
<tr>
<td>Form-overlap prime</td>
<td>bright ~ BRIGHT</td>
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<tr>
<td>Semantic-associate prime</td>
<td>rabbit ~ CARROT</td>
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<tr>
<td>Control prime</td>
<td>coffee ~ HAMMER</td>
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Visual masked priming

• The prime is **masked** (i.e. obscured from participants’ conscious awareness):
  1. by being presented for only a brief duration (~50 ms).
  2. by being presented between the forward mask and target (which acts as a backward mask).
  3. by being presented in a different font (case/size) from the target.
  4. by all components of the trial being presented in a monospaced font (e.g. Courier New).

• Participants may perceive that something “flickered” onscreen, but typically they remain unaware of the prime.
Visual masked priming

- In any priming study, participants will respond to (e.g. judge the lexicality of) a number of targets (e.g. real words and non-words).
  - You should use an equal number of each type of target. For lexical decision, you should use an equal number of real words and non-words as targets.

- In VMP, participants should respond to each target once and only once.
  - This means that if you have multiple possible primes per targets, different sets of participants will need to respond to the target when primed by each possible prime (e.g. ½: nurse priming DOCTOR; ½: curse priming DOCTOR).
  - Prime-target pairs should be counter-balanced (i.e. participants respond to an equal number of possible prime-target pair types).
  - To assess priming effects, you compare responses to the experimental primes with responses to the control primes.

<table>
<thead>
<tr>
<th>Participant 1</th>
<th>Participant 2</th>
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<tbody>
<tr>
<td>nurse ~ DOCTOR</td>
<td>curse ~ DOCTOR</td>
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<tr>
<td>shin ~ CAPTAIN</td>
<td>ship ~ CAPTAIN</td>
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What can we use visual masked priming to study?

• We use visual masked priming to study the processes which underly visual word recognition and the factors (e.g. frequency, morphological complexity) which determine how words are stored and accessed.

• It is well-established (since at least Preston (1935)) that words which have been experienced more frequently are processed faster and more accurately (the **word frequency effect**). This has been found using:
  • visual duration thresholds (Howes and Solomon 1951);
  • lexical decision (e.g. Connine et al. 1990; Forster and Chambers 1973);
  • naming (e.g. Forster and Chambers 1973);
  • eye-tracking (e.g. Just and Carpenter 1980; Raney and Rayner 1995);
  • semantic and syntactic categorization (Monsell et al. 1989).
What can we use visual masked priming to study?

• In the original masked priming study, Forster and Davis (1984) explored the effects of repetition priming and word frequency on lexical decision.
  • In lexical decision, readers are usually faster to judge high-frequency (HF) words as real words than they are to judge low-frequency (LF) words.
  • Readers are faster to judge HF and LF words when primed by a supraliminal repetition prime, AND the effect is greater for LF words such that they are equally fast to judge HF and LF words (the frequency attenuation effect).
  • When the primes are masked, HF and LF words exhibit an equivalent priming effect such that HF words are still judged faster than LF words.
  • Their interpretation was the supraliminal repetition priming taps into episodic memory, rather than purely involving the lexical processing system.
What can we use visual masked priming to study?

• The lack of a frequency attenuation effect (and the non-involvement of episodic memory) is one way supraliminal and masked priming differ.

• Another difference is that priming effects are short-lived when the primes are masked compared to when they are supraliminal.
  • Supraliminal repetition priming effects can cross modalities and last for weeks (long-lag priming) (Scarborough et al. 1977, 1979), suggesting that episodic memory, and not simply lexical activation, is involved.
  • In contrast, masked priming effects don’t extend beyond a single trial.

• Semantic priming (e.g. nurse priming DOCTOR) is also rare when masked.
  • One possibility is that priming influences lexical access, and the potential effects of semantics play a role only post-lexical access.
What can we use visual masked priming to study?

- What role does **form** (i.e. the shape of a word: the letters which comprise a word and their order) play in activating potential lexical candidates?

- This has been studied using masked **form/neighbor priming** (i.e. where the prime and target overlap in some number of letters).
  - Form primes which share all but one letter with the target (e.g. *cast* priming *PAST*) activate the target, but the actual priming effect observed depends on the number of neighbors also activated by the prime (Forster et al. 1987).
  - Few neighbors (e.g. *able* priming *AXLE*) -> facilitation.
  - Many neighbors (e.g. *cast* priming *PAST*) -> inhibition.

- This reflects the increased amount of competition between candidates.
What can we use visual masked priming to study?

- The role of form overlap in lexical processing has also been studied using transposed-letter priming (i.e. where the prime and target overlap in all of their letters, but the order of the letters is switched; e.g. blot priming BOLT).
- Comparable facilitation is obtained by repetition (e.g. answer-ANSWER) and TL primes (e.g. anwser-ANSWER) in lexical decision (Forster et al. 1987).
- Greater facilitatory priming is obtained for longer words than shorter ones (e.g. 7-letters vs. 5-letters) (Schoonbaert and Grainger 2004; Humphreys et al. 1990).
- Primes formed by transposing the outer letters of a word (e.g. ujdge-JUDGE) elicit less priming than do primes formed by transposing the inner letters of a word (e.g. jugde-JUDGE) (Schoonbaert and Grainger 2004).
- These results suggest that letter strings comprised of the same letters as the target also activate the target, with some restrictions (e.g. based on length).
What can we use visual masked priming to study?

• What do you think matters more for lexical activation? That the input string has the same consonants as the target or the same vowels?

• Having the same consonants seems to be more important, as has been shown with **subset priming** (i.e. where the prime consists of a subset of the target’s letters; e.g. *csn* priming *CASINO*) (e.g. Anderson and Geary 2019).
  • Subset primes consisting of the consonant letters of the target facilitate target recognition (e.g. *csn-CASINO*), while subset primes consisting of the vowel letters do not (e.g. *aia-ANIMAL*) (Duñabeitia and Carreiras 2011).

• On average languages have more consonant letters than vowels, meaning there are more possible combinations of consonants than of vowels.

• This means that fewer words share consonants than share vowels, making consonants a more effective cue to word identity than vowels.
What can we use visual masked priming to study?

- Another common use of visual masked priming is to explore how readers process morphologically complex words. Do readers decompose such words into their constituent morphemes during word processing?
  - We study this using morphological priming (i.e. where the prime and target share some morpheme; e.g. *darkness* priming *DARK*).
  - Rastle et al. (2004) obtained facilitatory priming between words which share a transparent morphological relationship (e.g. *cleaner*-CLEAN).
  - They also found priming between words sharing an apparent morphological relationship (e.g. *corner*-CORN) but not words overlapping similarly in letters but lacking such a relationship (e.g. *brothel*-BROTH).
  - Their interpretation: readers decompose anything that looks morphologically complex (e.g. *corner* -> *corn* + -er), and these morphemes subsequently mediate lexical processing.
What can we use visual masked priming to study?

• We similarly use visual masked priming to explore the role of semantics in contributing to morphological processing.
  • Typically words which share a morpheme also share a semantic relationship, but exceptions can be found (e.g. *receive, deceive, conceive*).
  • Forster and Azuma (2000) obtained facilitatory priming by primes sharing a bound root morpheme with the target but lacking a semantic relationship (e.g. *submit-PERMIT*) (see also Frost et al. (1997) for a similar result in Hebrew).
  • This suggests that semantics is NOT involved in morphological processing.
  • More recent research has found graded effects of semantic relatedness on morphological priming (e.g. Feldman et al. 2015, Jared et al. 2017; see also Milin et al. (2017) for a review of such findings), suggesting some role for semantics.
What can we use visual masked priming to study?

• Another use of visual masked priming is to explore how the lexicons of a multilingual reader interact during lexical processing in one language.
  • We study this using translation priming (i.e. where the prime and target are translation equivalents; e.g. English vampire priming Spanish vampiro).
  • Typically, cognates (e.g. Spanish rico priming English RICH) elicit greater facilitatory priming than do non-cognates (e.g. mesa priming TABLE).
  • Moreover, priming is greater with L1 primes and L2 targets (forward priming) than with L2 primes and L1 targets (backward priming) (e.g. Gollan et al. 1997).
    • This suggests that representations from the two lexicons interact, but the connections from L1-to-L2 representations are stronger than those from L2-to-L1 representations.
    • Backward priming is more common with bilinguals who are especially proficient in the L2 (e.g. Basnight-Brown and Altarriba 2007; Duñabeitia et al. 2010; Dimitropoulou et al. 2010).
What can we use visual masked priming to study?

• Finally, another use of visual masked priming has been to explore the limits of the word processor: How many words can we process at once?
• We can study this by displaying an intervenor between the prime and target and assessing whether a priming effect still occurs after word-interveners.
• Forster (2009, 2013) has found that form priming is eliminated and repetition priming is reduced with a masked intervenor, suggesting that the processor cannot handle three words at once (i.e. the prime, intervenor, and target).
Summary of types of priming

- **Repetition priming** (i.e. the prime and target are identical)
- **Semantic priming** (i.e. the prime and target share semantics)
- **Form/Neighbor priming** (i.e. the prime and target share some but not all of the same letters)
- **Transposed-letter priming** (i.e. the prime and target consist of the same letters but in a different order)
- **Subset priming** (i.e. the prime consists of a subset of the letters contained in the target)
- **Morphological priming** (i.e. the prime and target share a morpheme; may or may not share semantics)
- **Translation priming** (i.e. the prime and target are translation equivalents; may be cognate or non-cognate)

Examples:

- `answer` ~ `ANSWER`
- `nurse` ~ `DOCTOR`
- `antwer` ~ `ANSWER`
- `anwser` ~ `ANSWER`
- `csn` ~ `CASINO`
- `cleaner` ~ `CLEAN`
- `submit` ~ `PERMIT`
- `rico` ~ `rich`
- `mesa` ~ `TABLE`
How do we construct a visual masked priming study?

• To conduct a visual masked priming study, you need only a few pieces of hardware and software (which you may already have and/or which is free):
  • DMDX and TimeDX (free software you can download [here](#)).
  • A word processor (e.g. Microsoft Word) in which to write your DMDX script.
  • A computer running Windows OS (DMDX only works on Windows).
  • An input device for recording participants’ responses.
    • You can use a keyboard, but we prefer to use [Logitech F310 gamepads](#) in our lab, because they are cheap, reliable, and record accurately.
    • Commercial button boxes compatible with DMDX do not exist. 😞
  • Otherwise, you just need a **stimulus list** (i.e. your list of primes and targets) and the ability to write a DMDX script (more on this later).
How do we construct a visual masked priming study?

• Depending on your experimental task, you need an equal number of targets which require each possible type of response.
  • If lexical decision: Equal number of real words and non-words.
  • If semantic categorization: Equal number of category exemplars and non-exemplars.
  • You need to use an equal number to prevent participants from generating expectations about what the next response will be.

• Some tips for selecting targets:
  • Make sure that your real-word targets are of high enough frequency that participants can recognize them, and your non-word targets are plausible words and of roughly equal neighborhood density as the real words.
  • Depending on your language you may be able to use a non-word generator (e.g. Wuggy) to generate some of your stimuli (make sure to vet them!).
How do we construct a visual masked priming study?

• You should keep your items organized in a spreadsheet (e.g. Excel), which will be even more useful later when we generate our DMDX script.

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How do we construct a visual masked priming study?

• If possible, match each target with one of each possible type of prime (within-items design), rather than match each possible type of prime with a different target (between-items design).

  • This allows for a more valid comparison between priming conditions: with a between-items design, differences between the sets of targets may lead to differences in the effects observed in each priming condition.

• There are some situations in which you must use a between-items design.

  • Consider translation priming: individual words typically don’t have both a cognate and a non-cognate translation equivalent in other languages, so you need to use different targets for cognate vs. non-cognate primes.
How do we construct a visual masked priming study?

• Again, organize your items in a spreadsheet.

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How do we construct a visual masked priming study?

• If your experiment has a within-items design, then you also need to construct multiple **experimental lists**.
  • An experimental list is a list of items which contains each target once, paired with one and only one of its possible primes. Each type of prime-target pair should occur an equal number of times per list, and each target should occur with each of its primes across all lists (**Latin square design**).
  • Your total number of lists equals the total number of priming conditions.
    • If you have 2 types of primes (e.g. repetition vs. control), you need 2 lists.
    • Each list will contain an equal number of repetition primes, and an equal number of control primes, and the 2 lists will not overlap.
  • You then assign participants (at random) to complete one and only one list.
How do we construct a visual masked priming study?

- In our sample stimuli list, there are 12 targets and 2 prime types.
- Thus, we construct 2 lists, each containing all 12 targets.
- Across the 2 lists, each target is paired with a different type of prime.
- Each list will contain 6 repetition primes and 6 control primes total.

<table>
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<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
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</tbody>
</table>
How do we construct a visual masked priming study?

• Once you have settled on an experimental task (are you doing lexical decision? semantic categorization? something else?), identified all of your items, and assigned items to lists: congratulations! You’re ready to write yourself a DMDX script.

• For me, item selection is the most difficult and time-consuming part.

• Once you get a hang of DMDX scripting, this should be the easy step.
Questions?