Specific visual features guide approach behavior in laboratory mice

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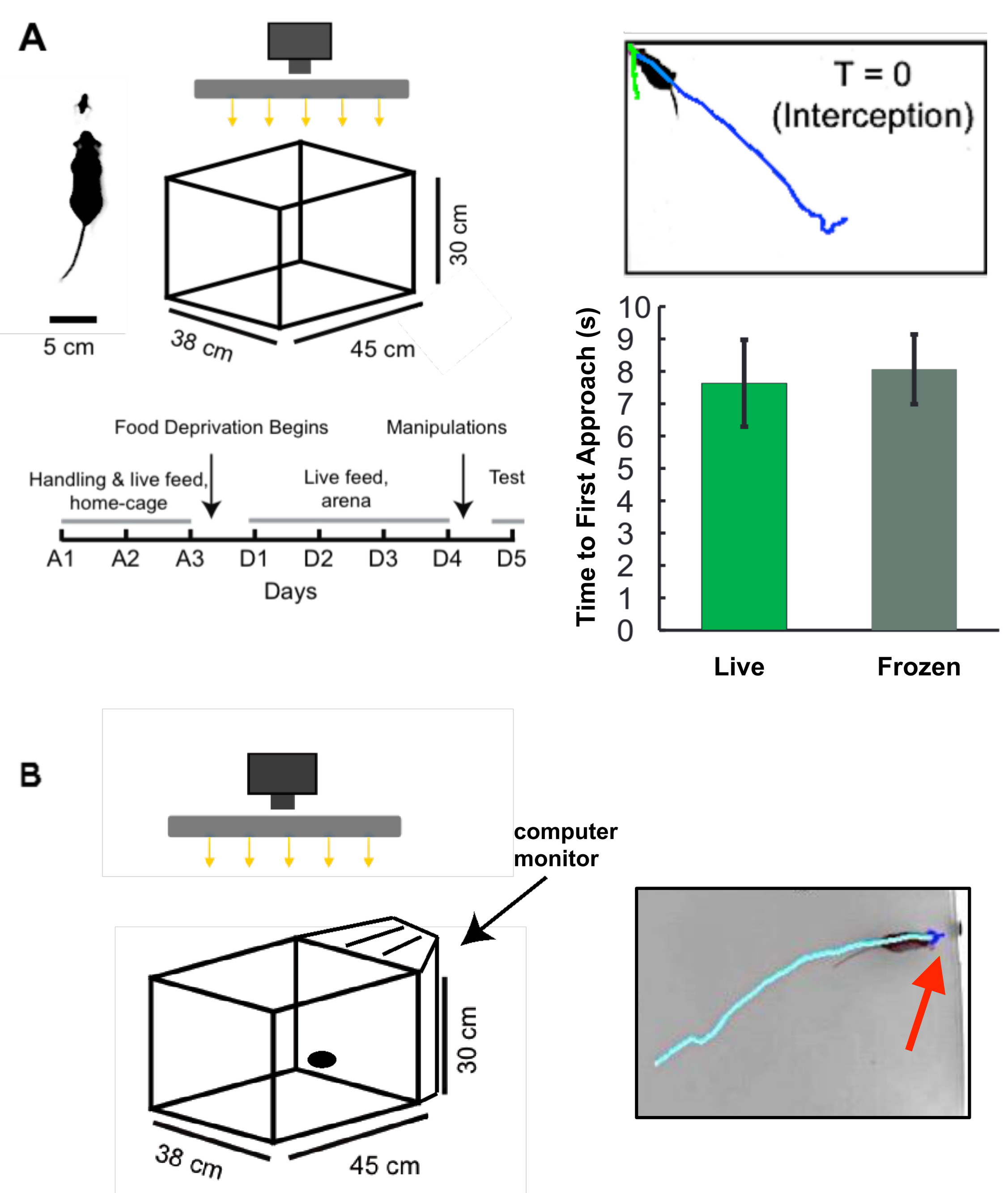
Introduction

Using the mouse as a model for vision has given us insight into the neural circuitry underlying vision. However, we still do not fully understand how specific visual information naturally signals reward and drives approach behavior in the mammalian brain. Previous work has shown that laboratory mice use vision to perform prey-capture, a natural motivated approach behavior in many species[1]. Here, we build on this observation and show that laboratory mice also robustly approach virtual stimuli that have visually similar features to that of live insect prey. We precisely manipulated the size and contrast of "virtual insects" and quantified the approach behavior towards them in order to determine which parameters best evoke orienting and approach behaviors in mice. We also inhibited the function of primary visual cortex in order to understand which visual systems mediate these conserved behaviors and visual functions. Therefore, our work will allow us to take full use of the mouse model to understand the neural circuit basis of visually guided appetitive behavior.

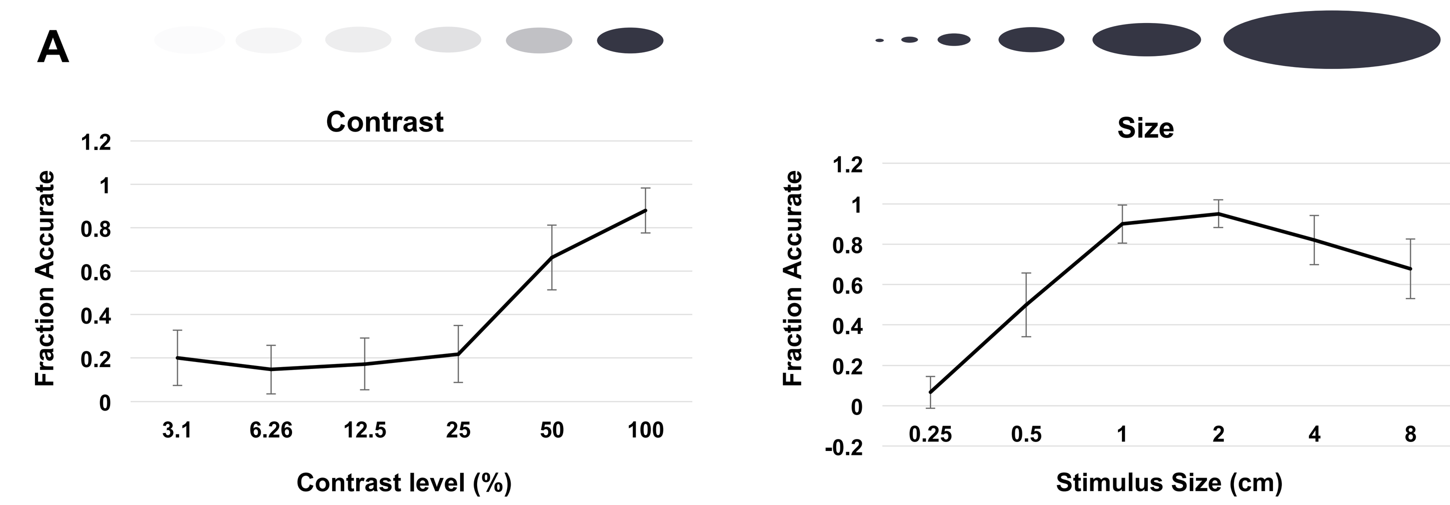
1. Hoy JL., Yavorska I., Wehr M., Niell CM. Vision drives accurate approach behavior during prey capture in laboratory mice. Curr Biol. 2016

Quantifying Prey Capture Behavior - Methods



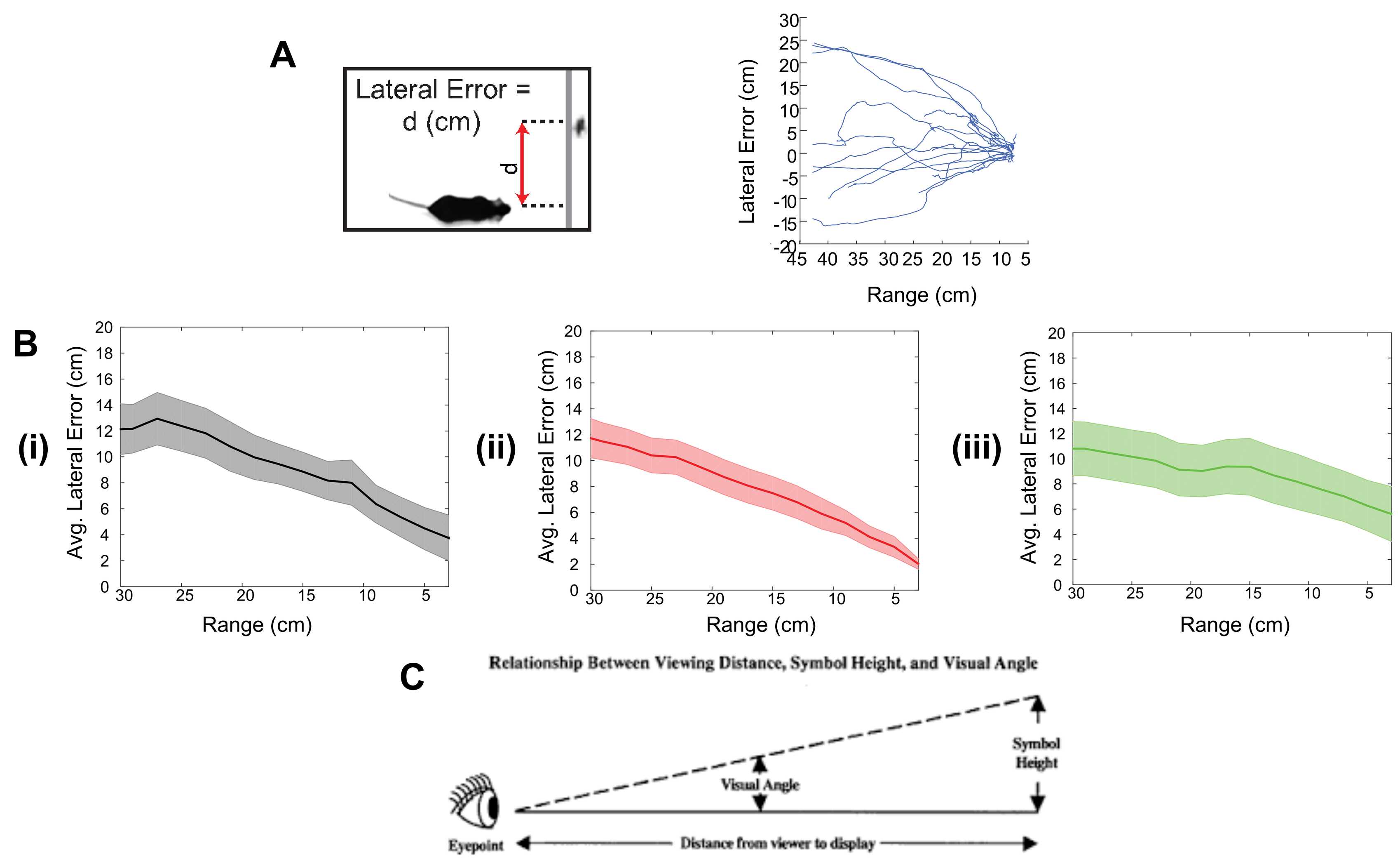
(A) Schematic of arena where training protocol was performed and live prey capture behavior was recorded. Here, we show the tracking of a mouse that is leading to target interception (T=0) (right, top). We the time to first approach targets that were either live (moving) or frozen (non-moving). This allowed us to determine whether motion of the prey was necessary for approach behavior in mice (right, bottom). Since motion was not required, we continued to investigate the effects of virtual stimuli on approach behavior. **(B) Schematic of arena where virtual stimuli approach behavior was recorded.** Here, we show the tracking of a mouse that is approaching a virtual target presented on a computer monitor screen (red arrow) that has replaced one side of the original arena (right).

Size and Contrast Determine Accurate Approach Behavior



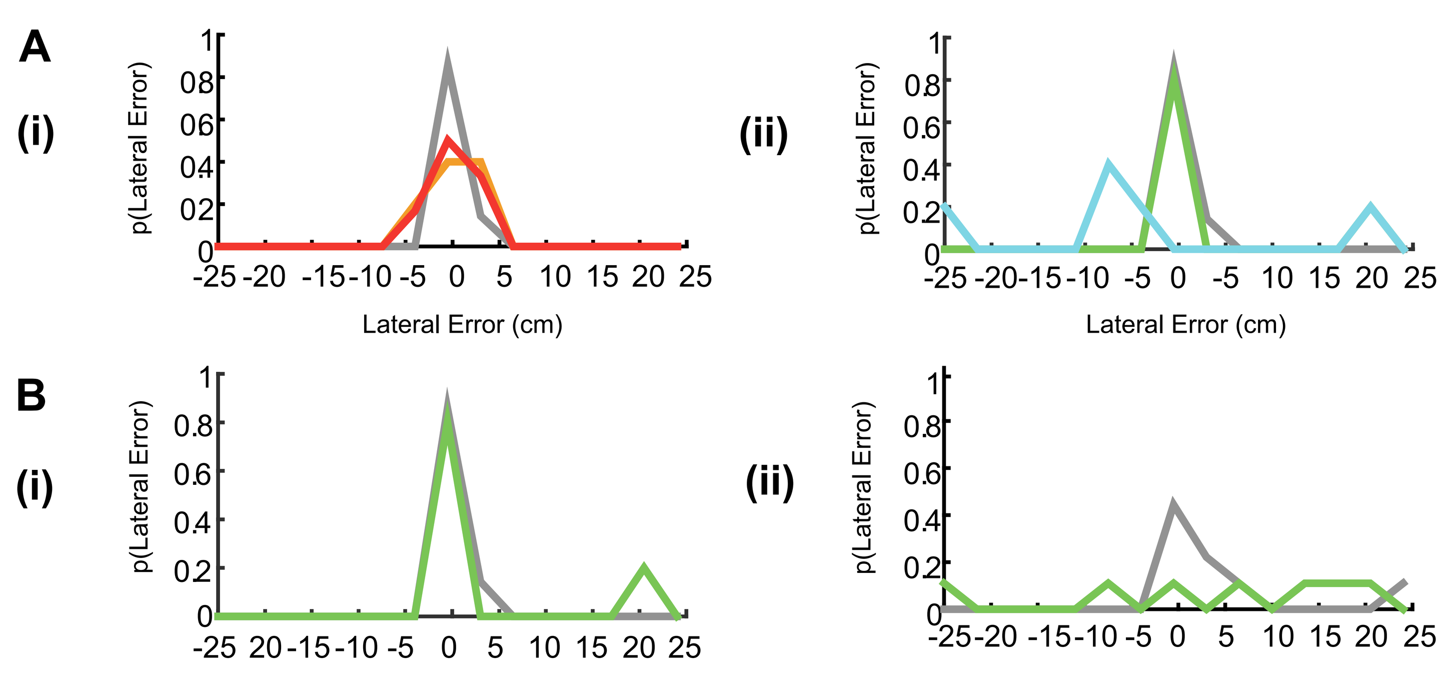
(A) Response curves to contrast and size stimuli. Contrast stimuli (left) varied stepwise from 3.1% up to 100% contrast, where 0% contrast (blank screen) was used as a control. Size stimuli (right) varied stepwise from 0.25cm up to 8cm, with 2cm representing the average size of a live cricket. The accuracy of approaches made to each differing contrast and size stimulus were separately quantified.

A Specific Size of Stimulus Triggers Approach



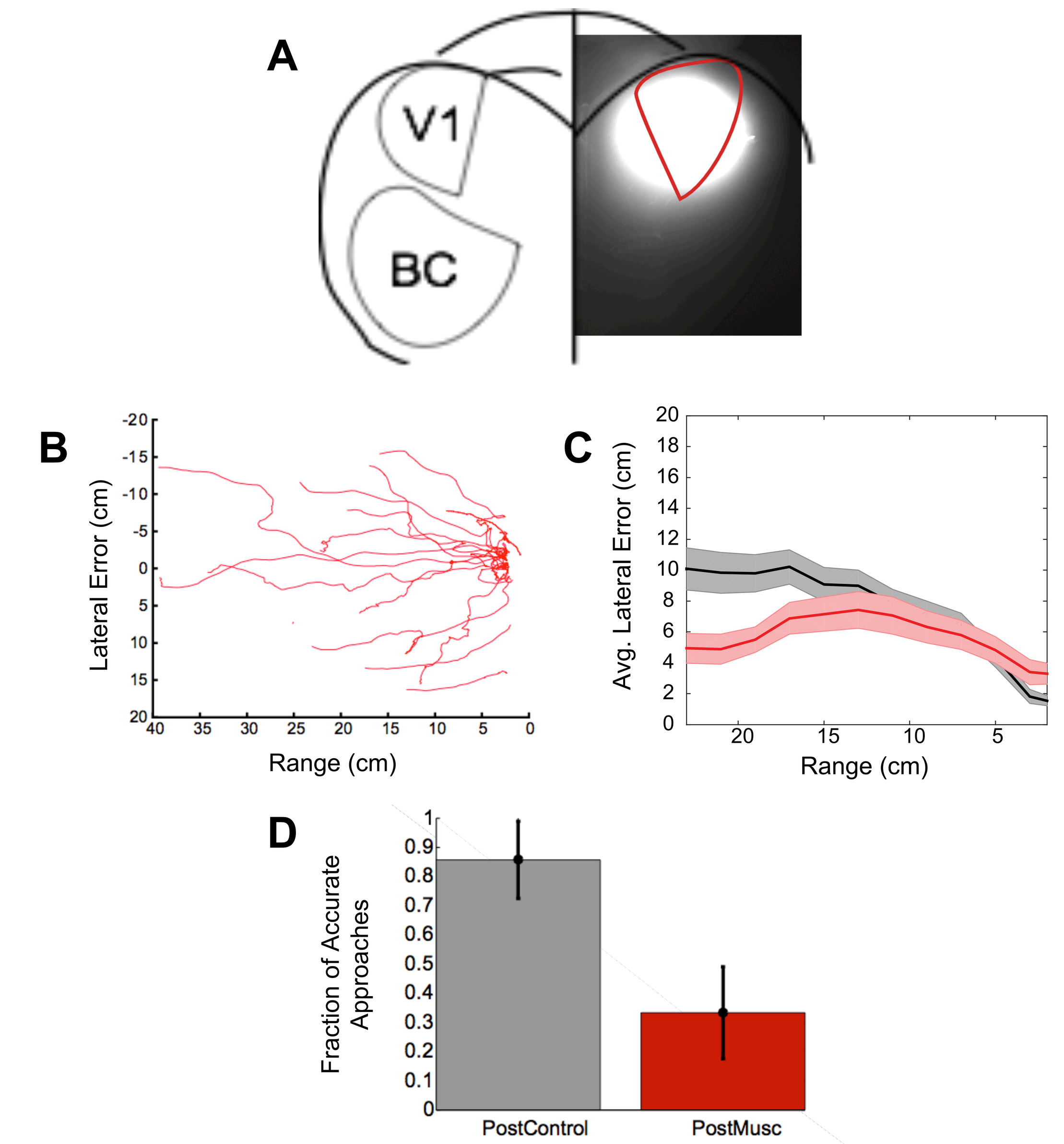
(A) Mouse tracks in terms of lateral error at a given distance (Range) from a 2cm virtual target over multiple approaches. An error of 0 indicates the mouse's head is touching the target. Convergence of approach tracks occurs at 15cm away from target. **(B)** Average distance at which approaches were made toward a **(i)** 2cm, **(ii)** 4cm, and **(iii)** 1cm virtual target. Shaded regions denote standard error. **(C)** Schematic of relationship between viewing distance of object, object height, and visual angle.

Prey-Capture Experience Modulates Stimulus Detection



(A) Distribution of accuracy measurements for all approaches made toward virtual stimuli **(i)** larger and **(ii)** smaller than 2cm (gray line). We expressed accuracy in terms of the probability of observing a given error over the entire distribution of errors for each group (p(Accuracy = x)). Line colors: orange = 4x larger (8cm), red = 2x larger (4cm), green = 0.5x smaller (1cm), cyan = 0.25x smaller (0.5cm). **(B)** Distribution of accuracy measurements for approaches made toward 2cm and 1cm virtual stimuli for **(i)** experienced and **(ii)** inexperienced mice.

Primary Visual Cortex Modulates Prey- Capture Behavior



(A) Schematic of mouse brain with image of the right hemisphere, primary visual cortex (V1) outlined in red, after injection with fluorescent muscimol. Injections were bilateral and centered over V1. **(B)** Mouse tracks approaching a 2cm virtual target over multiple trials with bilateral muscimol injections. **(C)** Average lateral error when the virtual target was 2cm for control (gray) and muscimol injected (red) mice. The change in slopes indicate the beginning of approaches. Shaded regions denote standard error. **(D)** Fraction of approaches that were accurate for control mice (gray) and muscimol injected mice (red) over multiple trials.

Conclusions

- Mice orient towards and approach virtual stimuli that are higher in contrast and are similar in size to real prey.
- Approach behavior is triggered by a specific stimulus size which tells us what information the visual system needs to initiate the behavior.
- Experience is necessary for mice to produce accurate approach behavior toward virtual stimuli.
- The primary visual cortex (V1) plays a role in accurate approach behavior in mice

Future Directions

- Test inhibition of the primary visual cortex (V1) on sizes and contrasts below and above the average cricket size and respective contrast
- Determine whether changes in elevation or motion of virtual stimuli affect accurate approach behavior.
- Measure head angle in addition to tracked approach paths to better analyze accuracy of approaches.
- Utilize a larger arena to compensate for farther approach distances.

Acknowledgments

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