

a)

$$\frac{\langle e_1, E, S \rangle \Downarrow \langle v_1, S' \rangle \quad \langle e_2, E, S' \rangle \Downarrow \langle v_2, S'' \rangle}{\langle (\text{before } e_1 e_2), E, S \rangle \Downarrow \langle v_1, E, S' \rangle}$$

b)

$$\frac{e = E(v_2) \quad \langle e, E + \{v_1 \rightarrow e\}, S \rangle \Downarrow \langle v, S' \rangle}{\langle (\text{alias } v_1 v_2 e), E, S \rangle \Downarrow \langle v, S' \rangle}$$

$$E_1 = \{u \rightarrow e\}; E_2 = \{u \rightarrow e; y \rightarrow e\}$$

$$S_1 = \{u \rightarrow 1\}; S_2 = \{u \rightarrow 1, y \rightarrow 1\}; S_3 = \{u \rightarrow 3, y \rightarrow 3\}; S_4 = \{u \rightarrow 8, y \rightarrow 8\}$$

$\vdash E_1, S_1 \rightarrow S_2$

$$\frac{\overline{\langle 3, E_2, S_2 \rangle} \parallel \overline{\langle 3, S_2 \rangle}}{\langle (\text{alias } y \ 3), E_2, S_2 \rangle \parallel \langle 3, S_2 \rangle} \quad (\text{Int})$$

$$\frac{\overline{\langle 5, E_2, S_3 \rangle} \parallel \overline{\langle 5, S_3 \rangle}}{\overline{\langle (+ \ x \ 5), E_2, S_3 \rangle} \Downarrow \overline{\langle 8, S_3 \rangle}} \quad (\text{Add})$$

$$\frac{\overline{\langle (\text{alias } y \ 3), E_2, S_3 \rangle} \parallel \overline{\langle 8, S_4 \rangle}}{\langle (\text{alias } y \ 3), E_2, S_3 \rangle \Downarrow \langle 8, S_4 \rangle} \quad (\text{Assign})$$

$$\frac{\overline{\langle y, E_1, S_1 \rangle} \parallel \overline{\langle 1, S_2 \rangle}}{\langle (\text{before } (\text{alias } y \ 3) (\text{alias } y \ (+ \ x \ 5))), E_2, S_2 \rangle \Downarrow \langle 3, S_4 \rangle} \quad (\text{var})$$

before

$$\frac{\overline{\langle (\text{alias } y \ 3) (\text{before } (\text{alias } y \ 3) (\text{alias } y \ (+ \ x \ 5))), E_2, S_2 \rangle} \Downarrow \overline{\langle 3, S_4 \rangle}}{\overline{\langle (\text{alias } y \ 3) (\text{before } (\text{alias } y \ 3) (\text{alias } y \ (+ \ x \ 5))), E_1, S_1 \rangle} \Downarrow \overline{\langle 3, S_4 \rangle}} \quad (\text{Alias})$$

$$\frac{\overline{\langle x, E_2, S_4 \rangle} \Downarrow \overline{\langle 8, S_4 \rangle}}{\langle x, E_2, S_4 \rangle \Downarrow \langle 8, S_4 \rangle} \quad (\text{var})$$

$$\frac{\overline{\langle 1, \phi, \phi \rangle} \Downarrow \overline{\langle 1, \phi \rangle}}{\overline{\langle (+(\text{alias } y \ 3) (\text{alias } y \ (+ \ x \ 5))) \ x, E_1, S_1 \rangle} \Downarrow \overline{\langle 11, S_4 \rangle}} \quad (\text{Add})$$

$$\frac{\overline{\langle (\text{let } x \ 1 (+ (\text{alias } y \ 3) (\text{alias } y \ (+ \ x \ 5))) \ x), E_1, S_1 \rangle} \Downarrow \overline{\langle 11, S_4 \rangle}}{\langle (\text{let } x \ 1 (+ (\text{alias } y \ 3) (\text{alias } y \ (+ \ x \ 5))) \ x), \phi, \phi \rangle} \Downarrow \langle 11, \phi \rangle \quad (\text{Let})$$