Side-Effect

Code doing anything other than just returning value
Anything affecting evaluation *other* program itself

Fb eval: $e \Rightarrow v$
FbS eval: $\langle S, e \rangle \Rightarrow \langle S, v \rangle$

$4 + 1 \Longrightarrow 5$

$\langle S, (\text{Function } x \to !x) \ldots \rangle \Longrightarrow$
$\Longrightarrow$

Let x = Ref 4 In
Let y = !x In
Let _ = (x := 8) In
Let z = !x In

Sequence and While

$e ::= \ldots \mid e ; e \mid \text{While } e \text{ Do } e$

encode $e_1 ; e_2$ as Let _ = e_1 In e_2

Fb ;
$$\frac{e_1 \Rightarrow v_1 \quad e_2 \Rightarrow v_2}{e_1 ; e_2 \Rightarrow v_2}$$

Let x = Ref 5 In
x := 8 ; !x

FbS ;
$$\frac{\langle S_1, e_1 \rangle \Rightarrow \langle S_2, v_1 \rangle \quad \langle S_2, e_2 \rangle \Rightarrow \langle S_3, v_2 \rangle}{\langle S_1, e_1 ; e_2 \rangle \Longrightarrow \langle S_3, v_2 \rangle}$$

While False
$$\frac{\langle S_1, e_1 \rangle \Rightarrow \langle S_2, \text{False} \rangle}{\langle S_1, \text{While } e_1 \text{ Do } e_2 \rangle \Longrightarrow \langle S_2, \text{False} \rangle}$$

While True
$$\frac{\langle S_1, e_1 \rangle \Rightarrow \langle S_2, \text{True} \rangle \quad \langle S_2, e_2 \rangle \Rightarrow \langle S_3, v_2 \rangle \quad \langle S_3, \text{While } e_1 \text{ Do } e_2 \rangle \Longrightarrow \langle S_4, v_4 \rangle}{\langle S_1, \text{While } e_1 \text{ Do } e_2 \rangle \Longrightarrow \langle S_4, v_4 \rangle}$$

While True Do False $\not\Longrightarrow$

Exceptions

FbX : Fb with exceptions

Kind of control operation

throw / raise	if
return	match
goto	
break	
continue	

$e ::= \cdots \mid k\ e \mid \text{Raise } e \mid \text{Try } e \text{ With } k\ x \to e$

$k ::= \#[A\text{-}Z][A\text{-}Za\text{-}z0\text{-}9\_]^*$

$v ::= \cdots \mid k\ v \mid \text{Raise } v$

$k_1 = \#Foo$

$e \Longrightarrow v$

Try

(Function b →

If b Then Raise #Foo 4 Else 5) True

With

#Foo y → y

Raise $\dfrac{e \Longrightarrow v}{\text{Raise } e \Longrightarrow \text{Raise } v}$

Exception $\dfrac{e \Longrightarrow v}{k\ e \Longrightarrow k\ v}$

Catch $\dfrac{e_1 \Longrightarrow v_1 \quad v_1 = \text{Raise } v_2 \quad v_2 = k\ v_3 \quad e_2[v_3/x] \Longrightarrow v_4}{\text{Try } e_1 \text{ With } k\ x \to e_2 \Longrightarrow v_4}$

(syntax: e_2; evaluation: v_4)

Succeed $\dfrac{e_1 \Rightarrow v_1 \quad v_1 \text{ not of the form Raise } v_2}{\text{Try } e_1 \text{ With } k\ x \to e_2 \Longrightarrow v_1}$

Try 4 + Raise #Foo 5

With (Raise #Foo 5) + 4

#Foo x → x

+ Raise Right $\dfrac{e_1 \Longrightarrow v_1 \quad e_2 \Longrightarrow \text{Raise } v_2 \quad v_1 \text{ not of form Raise } v}{e_1 + e_2 \Longrightarrow \text{Raise } v_2}$

Raise Raise $\dfrac{e \Longrightarrow \text{Raise } v}{\text{Raise } e \Longrightarrow \text{Raise } v}$

$3 + \underbrace{f(4)}_{exc}$