

Execution Semantics of Pattern/Scope Combinations

Pattern/scope combinations	QRE semantics and verdict procedure
always P after Q	$\text{EoE} \mid (\text{Q P}^* (\neg[P] \mid \text{EoE}))$ <hr/> <pre> graph LR match([match]) -- "¬[P] = null" --> T((T)) match -- "¬[P] ≠ null" --> bot((⊥)) </pre>
always P after Q until R	$\text{EoE} \mid (\text{Q P}^* (\neg[P] \mid \text{R} \mid \text{EoE}))$ <hr/> <pre> graph LR match([match]) -- "EoE = null" --> J(()) match -- "EoE ≠ null" --> T((T)) J -- "¬[P] ≠ null" --> bot((⊥)) J -- "¬[P] = null" --> Q((?)) </pre>
always P before Q	$\text{EoE} \mid \text{Q} \mid \neg[P]$ <hr/> <pre> graph LR match([match]) -- "¬[P] = null" --> T((T)) match -- "¬[P] ≠ null" --> bot((⊥)) </pre>
always P between Q and R	$\text{EoE} \mid (\text{Q P}^* \neg[P] \text{P}^* (\text{R} \mid \text{EoE}))$ <hr/> <pre> graph LR match([match]) -- "EoE = null" --> J(()) match -- "EoE ≠ null" --> T((T)) J -- "¬[P] ≠ null" --> bot((⊥)) J -- "¬[P] = null" --> Q((?)) </pre>
always P globally	$\text{EoE} \mid \neg[P]$ <hr/> <pre> graph LR match([match]) -- "¬[P] = null" --> T((T)) match -- "¬[P] ≠ null" --> bot((⊥)) </pre>

Table 1: Semantics of Universality patterns as QREs and verdict procedures.

Pattern/scope combinations	QRE semantics and verdict procedure
exists [2,3] P after Q	$\text{EoE} \mid (\underline{Q} (\neg[P]^* P' (\neg[P]^* \underline{P} (\neg[P]^* \underline{P} (\neg[P]^* P' \mid \text{EoE}) \mid \text{EoE}) \mid \text{EoE}) \mid \text{EoE}))$ <hr/>
exists [2,3] P after Q until R	$\underline{\text{EoE}} \mid (Q (\neg[P]^* P' (\neg[P]^* \underline{P} (\neg[P]^* \underline{P} (\neg[P]^* P' \mid R \mid \underline{\text{EoE}}) \mid R \mid \underline{\text{EoE}}) \mid R \mid \underline{\text{EoE}}) \mid R \mid \underline{\text{EoE}}) \mid R \mid \underline{\text{EoE}}))$ <hr/>
exists [2,3] P before Q	$\neg[P]^* P' (\neg[P]^* \underline{P} (\neg[P]^* \underline{P} (\neg[P]^* P' \mid Q \mid \text{EoE}) \mid Q \mid \text{EoE}) \mid Q \mid \text{EoE}))$ <hr/>
exists [2,3] P between Q and R	$\underline{\text{EoE}} \mid Q \neg[P,R]^* (\underline{P} \neg[P,R]^*)^* (R \mid \underline{\text{EoE}})$ <hr/>
exists [2,3] P globally	$\neg[P]^* P' (\neg[P]^* \underline{P} (\neg[P]^* \underline{P} (\neg[P]^* P' \mid \text{EoE}) \mid \text{EoE}) \mid \text{EoE}) \mid \text{EoE})$ <hr/>

Table 2: Semantics of Existence patterns as QREs and verdict procedures.

Pattern/scope combinations	QRE semantics and verdict procedure
never P after Q	$\text{EoE} \mid (Q \text{ .*? } (\underline{P} \mid \text{EoE}))$ <hr/> <pre> graph LR match([match]) -- "P = null" --> T((T)) match -- "P ≠ null" --> bot((⊥)) </pre>
never P after Q until R	$\underline{\text{EoE}} \mid (Q \text{ .*? } (\underline{P} \mid R \mid \underline{\text{EoE}}))$ <hr/> <pre> graph LR match([match]) -- "EoE = null" --> node(()) match -- "EoE ≠ null" --> T((T)) node -- "P ≠ null" --> bot((⊥)) node -- "P = null" --> Q((?)) </pre>
never P before Q	$\text{EoE} \mid Q \mid \underline{P}$ <hr/> <pre> graph LR match([match]) -- "P = null" --> T((T)) match -- "P ≠ null" --> bot((⊥)) </pre>
never P between Q and R	$\underline{\text{EoE}} \mid (Q \neg[P]^* (\underline{P} \neg[P]^*?)? (R \mid \underline{\text{EoE}}))$ <hr/> <pre> graph LR match([match]) -- "EoE = null" --> node(()) match -- "EoE ≠ null" --> T((T)) node -- "P ≠ null" --> bot((⊥)) node -- "P = null" --> Q((?)) </pre>
never P globally	$\text{EoE} \mid \underline{P}$ <hr/> <pre> graph LR match([match]) -- "P = null" --> T((T)) match -- "P ≠ null" --> bot((⊥)) </pre>

Table 3: Semantics of Absence patterns as QREs and verdict procedures.

Pattern/scope combinations	QRE semantics and verdict procedure
S precedes P after Q	$\text{EoE} \mid Q \text{ .*? } (\text{EoE} \mid S \mid \underline{P})$ <hr/> <pre> graph LR match([match]) -- "P = null" --> T((T)) match -- "P ≠ null" --> bot((⊥)) </pre>
S precedes P after Q until R	$\underline{\text{EoE}} \mid Q \text{ .*? } (\underline{\text{EoE}} \mid R \mid S \mid \underline{P})$ <hr/> <pre> graph LR match([match]) -- "EoE = null" --> node(()) match -- "EoE ≠ null" --> T((T)) node -- "P ≠ null" --> bot((⊥)) node -- "P = null" --> Q((?)) </pre>
S precedes P before Q	$\text{EoE} \mid Q \mid S \mid \underline{P}$ <hr/> <pre> graph LR match([match]) -- "P = null" --> T((T)) match -- "P ≠ null" --> bot((⊥)) </pre>
S precedes P between Q and R	$\underline{\text{EoE}} \mid Q \neg[P, R, S]^* (S \neg[R]^* \mid \underline{P} \neg[R]^*)? (\underline{\text{EoE}} \mid R)$ <hr/> <pre> graph LR match([match]) -- "EoE = null" --> node(()) match -- "EoE ≠ null" --> T((T)) node -- "P ≠ null" --> bot((⊥)) node -- "P = null" --> Q((?)) </pre>
S precedes P globally	$\text{EoE} \mid S \mid \underline{P}$ <hr/> <pre> graph LR match([match]) -- "P = null" --> T((T)) match -- "P ≠ null" --> bot((⊥)) </pre>

Table 4: Semantics of Precedence patterns as QREs and verdict procedures.

Pattern/scope combinations	QRE semantics and verdict procedure
S respondsTo P after Q	$\text{EoE} \mid Q \neg[P]^* (\underline{P} \neg[S]^* \underline{S} \neg[P]^*)^* (\underline{P} \neg[S]^*)? \text{EoE}$ <hr/> <pre> graph LR match([match]) -- " P = S " --> T((T)) match -- " P ≠ S " --> bot((⊥)) </pre>
S respondsTo P after Q until R	$\underline{\text{EoE}} \mid Q \neg[P,R]^* (\underline{P} \neg[R,S]^* \underline{S} \neg[P,R]^*)^* (\underline{P} \neg[R,S]^*)? (R \mid \underline{\text{EoE}})$ <hr/> <pre> graph LR match([match]) -- " P = S " --> node1(()) match -- " P ≠ S " --> bot((⊥)) node1 -- "EoE ≠ null" --> T((T)) node1 -- "EoE = null" --> q((?)) </pre>
S respondsTo P before Q	$\text{EoE} \mid Q \mid (\underline{P} \neg[S]^* \underline{S} \neg[P]^*)^* (\underline{P} \neg[S]^*)? (\text{EoE} \mid Q)$ <hr/> <pre> graph LR match([match]) -- " P = S " --> T((T)) match -- " P ≠ S " --> bot((⊥)) </pre>
S respondsTo P between Q and R	$\underline{\text{EoE}} \mid Q \neg[P,R]^* (\underline{P} \neg[R,S]^* \underline{S} \neg[P,R]^*)^* (\underline{P} \neg[R,S]^*)? (R \mid \underline{\text{EoE}})$ <hr/> <pre> graph LR match([match]) -- "EoE = null" --> node1(()) match -- "EoE ≠ null" --> T((T)) node1 -- " P ≠ S " --> bot((⊥)) node1 -- " P = S " --> q((?)) </pre>
S respondsTo P globally	$(\underline{P} \neg[S]^* \underline{S} \neg[P]^*)^* (\underline{P} \neg[S]^*)? \text{EoE}$ <hr/> <pre> graph LR match([match]) -- " P = S " --> T((T)) match -- " P ≠ S " --> bot((⊥)) </pre>

Table 5: Semantics of Response patterns as QREs and verdict procedures.